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Assistance System for the Teaching of Natural Numbers to Preschool Children with the Use of Artificial Intelligence Algorithms

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Abstract: This research was aimed at designing an image recognition system that can help increase children's interest in learning natural numbers between 0 and 9. The research method used was qualitative descriptive, observing early childhood learning in a face-to-face education model, especially in the learning of numbers, with additional data from literature studies. For the development of the system, the cascade method was used, consisting of three stages: identification of the population, design of the artificial intelligence architecture, and implementation of the recognition system. The method of the system sought to replicate a mechanic that simulates a game, whereby the child trains the artificial intelligence algorithm such that it recognizes the numbers that the child draws on a blackboard. The system is expected to help increase the ability of children in their interest to learn numbers and identify the meaning of quantities to help improve teaching success with a fun and engaging teaching method for children. The implementation of learning in this system is expected to make it easier for children to learn to write, read, and conceive the quantities of numbers, in addition to exploring their potential, creativity, and interest in learning, with the use of technologies.

Keywords: artificial intelligence; perceptron; ICT in education

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1. Introduction

Currently, information and communications technologies (ICTs) have a significant impact on all sectors of society. Their inclusion allows improvement and simplifies administrative and productive processes [1]. Similarly, ICTs have changed the way people conceive their environment and the way they carry out their activities. With the greater penetration of the Internet and the great availability of existing devices, users give priority to incorporating ICTs into their daily lives [2,3]. In addition, after the pandemic caused by Coronavirus Disease 2019 (COVID-19), society has seen the importance of technologies and how they allow the continuity of activities [4,5].

Education is one of the sectors with the greatest application of ICTs, since educational institutions have a direct relationship with them, both in their training and in their application [6,7]. ICTs provide multiple advantages to education since their use in the classroom currently represents fundamental support in the generation of content and development of activities. However, the inclusion of technologies in education is not simply focused on higher levels; their use in early childhood education is having a greater impact, as addressed by several studies [8,9]. In these studies, ICTs were highlighted in two types of use during early childhood education: to support the basic skills and attitudes of children and to support content and individual learning needs [10]. In addition to these types of use, it is essential to establish that use in early childhood education has greater penetration due to accessibility and usability in devices and applications. This means that today, the ease with which children handle any type of technological tool is observed. Therefore, in the face of any restrictive force and predetermined cognitive parameters that hinder the acceptance of technology in the educational event at an early age, it is necessary to generate an analysis that allows establishing its importance as a pedagogical tool, in such a way that its familiarization with technology allows dynamizing and innovating the teaching–learning process. From the studies reviewed, it follows that education with the use of ICTs is aimed at improving the teaching of preschool children by creating processes focused on their needs. This approach establishes the educational tradition, where teaching takes place with the teacher as the main actor [11,12], since, in this model, it is the teacher who determines what preschool children should learn and how they should do it. This implies that children have a passive role in their teaching, which makes them dependent on the knowledge and experience of the teacher [13,14].

In another group of studies reviewed, ICTs in education took a more active role and became educational aids for preschool children [15]. Their inclusion had a greater impact by converging with new educational methods such as active learning, flipped classrooms, and thinking-based learning [16,17]. The conceptualization of education and technology is functional if there are adequate conditions for their integration. For this reason, the studies that addressed this issue recommend that the integration be carried out in a staggered manner and that there be a teacher evaluation process that includes ICTs [18].

In this work, the use of technologies as an aid for teaching the numbers from 0 to 9 in preschool children is proposed. Therefore, ICTs are considered a means of teaching, which respond to the specific needs of preschool children [19]. In the participating population, there are a variety of problems, such as lack of motivation, distraction, and lack of early motor skills. For this reason, a didactic solution is proposed through a recognition system based on artificial intelligence (AI) [20,21]. For children, the ideal teaching method is a game, commonly used by tutors for children to learn a certain subject [22–24]. This work takes the methodology of tutors and implements an image recognition system, whereby preschoolers develop in a game environment, in which they write a number, and the system tries to recognize it [25,26]. Several works have studied this phenomenon and proposed concepts such as gamification, where children establish a teaching process and rewards using ICT [27,28]. This proposal is aimed at the creation of an AI algorithm that can recognize the numbers that children enter, serving as a didactic tool to improve the identification, writing, and conception of the quantity of a number. The results obtained serve as a guide for determining the importance of the use of ICT in teaching and if these are adaptable to the needs of an initial educational model.

2. Materials and Methods

For the design of the method, it was important to establish the objective population and the application process of the AI, as well as how it is applied within the educational model.

2.1. Population Identification

The population considered included preschool children between the ages of 3 and 4 years old belonging to an initial teaching center in Ecuador. This educational center aims to prepare preschool children to enter their stage of formal education. To meet this objective, the educational center offers a face-to-face education model, where, through games, preschool children learn to recognize figures, numbers, letters, etc. However, this process was affected in the 2020–2021 period due to COVID-19, where education migrated to a virtual education model.

In virtual education, preschool children used ICTs to address the different concepts and initial topics of their teaching. In this period, parents became the fundamental support for teaching. However, virtuality did not integrate ICTs throughout the educational process; this integration was limited to the use of videoconferencing platforms and learning management systems (LMSs) which, with the use of the Internet, became channels of interaction in a distance education model. The participant group consisted of 12 preschool children divided into two groups of six. In this study, one group was traditionally taught numbers, while the other group used the proposed system, to evaluate the differences and improvements between the two teaching methods.

2.2. AI Architecture Design

For the design of the architecture, it is essential to establish the needs of the users and adjust each phase to guarantee learning. The aim was the creation of a recognition system that allows preschool children in an early childhood education center to recognize the numbers from 0 to 9. For the process, it was considered that the system must be motivating; therefore, gamification was taken as an example aimed at, through interaction with the system, improving the teaching of numbers, both in their identification and in their writing and an understanding of their quantities. The AI architecture was based on image recognition; therefore, a supervised learning model was used, where the outputs of the algorithm are known since the data used to train the algorithm were previously labeled [29,30]. Figure 1 presents the environment and the necessary components for the implementation of the system. One of the components used as a monitor, in which the numbers from 0 to 9 are presented, acts as a guide for the child to reproduce the character on a blackboard. According to the reviewed studies, in traditional teaching methods, a preschool child learns by imitating and reproducing what is around them and from an interaction with the environment.

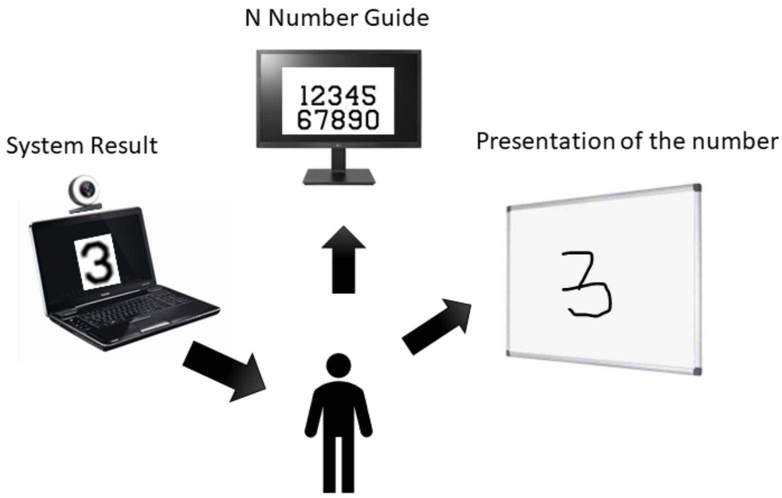


Figure 1. Natural number recognition system architecture and its components.

On the blackboard, the children try to write the number that the system randomly presents on the monitor; the number can also be presented by a tutor. The next components are the system and the start of the image recognition process. To achieve this, the algorithm takes a picture, processes it, and presents the answer on the laptop screen. The architecture is designed to be a teaching aid; however, tutoring for some time is important until preschoolers can correctly recognize numbers. Furthermore, the tutor has the task of telling the system if the recognized number is correct. Confirmation can be achieved by clicking or by voice command, previously configured in the algorithm.

The auxiliary recognition system is presented as a game for the child. In it, the child tries to improve the way she writes a number so that the system recognizes it and generates a correct answer. By including AI as an educational assistant, it is possible to enhance children’s attention, motivation, concentration, and effort, with a system that is not necessarily playful. With this system, the child assumes the role of tutor, since, in the mechanics of the game, he/she tries to teach the AI algorithm the N numbers so that it can identify the written number. Internally, what the algorithm does is an image recognition process where, through its database, it compares the image taken of the written number with the ones it has stored and which act as its knowledge base [23]. While the algorithm has an image base that allows it to recognize numbers, the child must try to write a number in such a way that it meets a certain similarity with the guide and is recognized by the algorithm, as shown in Figure 1.

2.3. Phases in the Implementation of a Number Recognition Model with AI

For the implementation, several phases have been designed that the model must fulfill to guarantee the recognition process. A flowchart, detailing the stages considered in the implementation of an AI algorithm for the recognition of N numbers, is presented in Figure 2. The implementation phases are described in a granular manner in Appendix A.

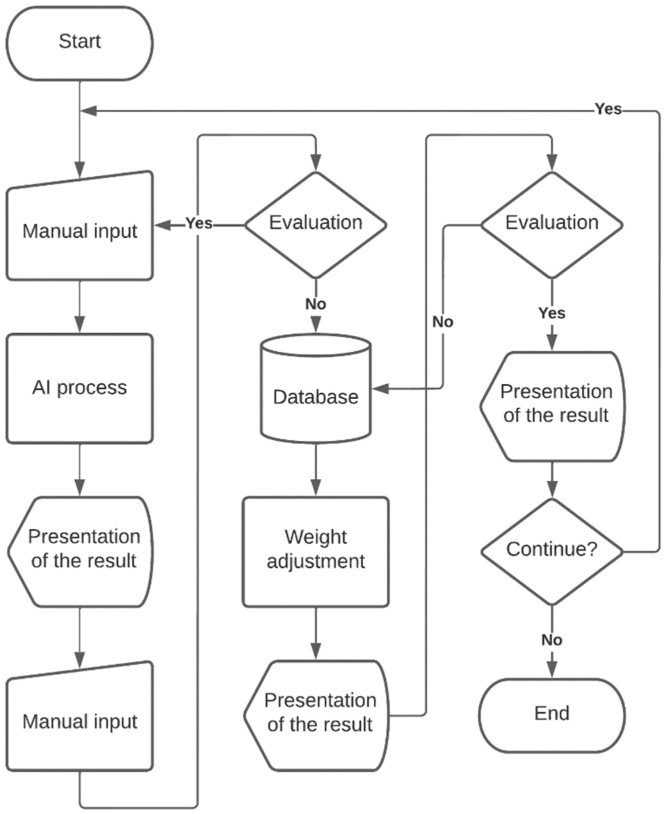


Figure 2. Flowchart for the design of a recognition system for teaching the number N to preschool children.

3. Results

The method of application of the system aims to validate whether the use of a system of recognition of natural numbers where 0 is included, helps the teaching of this subject in a population of preschool children.

3.1. Population Identification

The population participating in this study is preschool children between 3 and 4 years of age. This group of participants belongs to a children's center whose objective is to prepare them for the beginning of their school life. In this center, preschoolers learn to identify colors, shapes, numbers, vowels, animals, etc. Preschoolers in this age range learn effectively through games, songs, or videos that deal with topics in an interactive way. In addition, tutors should turn interaction spaces into ideal complements so that the teaching method adapts to the preschoolers' needs.

The population participating in this study are preschool children between 3 and 4 years of age. This group of participants belongs to a children's center whose objective is to prepare them for the beginning of their school life. In this center, the preschoolers learn to identify colors, shapes, numbers, vowels, animals, etc. Preschoolers in this age range learn effectively through games, songs, or videos that deal with topics in an interactive way. In addition, tutors should turn interactive spaces into ideal complements so that the teaching method adapts to the preschoolers' needs.

3.2. System Methodology

The methodology applied in the system helps children to learn from the point of view where they are the ones who teach the N numbers to the system. To achieve this goal, the child's ability to recognize a number is not enough; he/she must also replicate it. Therefore, the system works on number recognition and the child's motor skills when replicating numbers.

For the process, the system starts with the presentation of a number on a screen; this number is randomized between 0 and 9; the system can even be programmed to present the same number of objects. The children have a blackboard and black markers to replicate as best as possible the number or place the number that represents the number of objects presented. At this stage of the proposed work, we work with numbers, as shown in Figure 3, which exposes the process of sending a number to the system. At this stage, the tutor's support is necessary as he can use dot guides to train the children's motor skills. Once the number is written, the system takes a picture of the board and starts the recognition process. Once the image has been processed, it presents the result on another screen. The system has also been programmed so that you can pronounce the result in the form of a question. For example, is it a two? Or is it an eight? When generating this type of response, the system adopts a student posture and places the child in the role of a tutor.

Figure 3. Process for the presentation of a number, representation by the preschool children, and interpretation of the recognition system.

In the next stage, the system waits for confirmation whether the result is correct or not; the confirmation can also be by voice command. In other words, the whole process can be carried out through a conversation in this format in the case of an affirmative answer:

- System: it is a two?
- Boy: yes, it is a two
- System: are we still teaching?
- Child: "yes" or "no"

For a negative response, the format is as follows:

- System: it is a four?
- child: no
- System: what number is it?
- Boy: it is a two
- System: are we still teaching?
- Child: "yes" or "no"

In the negative confirmation, the interaction with the system is important, since when receiving feedback from the child indicating what number it is, it saves the image in its database to be able to adjust the weights and align them to how preschool children write numbers. In the same way, the end of the conversation is important to continue or exit the system; for voice recognition, the commands are previously configured in the system, and it cannot recognize others other than those that appear in the system.

3.3. Teaching Outcomes

In the results analysis review, a comparison is made between the two groups, the one using the recognition system and the one with a traditional teaching method. Generally, in these methods, children learn two numbers per week and combine this topic with other activities. For example, in the traditional system, the teaching of a number is accompanied by figures representing the number studied, songs, etc. are applied. These can be considered reinforcement or complementary activities. Therefore, the evaluation period is five weeks, during which the tutor accompanies the participants in the use of the system and evaluates the teaching with other activities. The evaluation activities do not contain a quantitative grade; they focus on verifying the level of education of all.

The evaluation of the process Is carried out during the five weeks that the recognition system is active; this evaluation is continuous and allows us to establish the progress of each child. The evaluation is qualitative, for which an evaluation guide is used to verify the extent of teaching, marking the level in a range from 1 to 10 to establish the teaching scale. Table 1 presents the evaluation criteria used by the tutor to verify the teaching of the subject. This tool is used in the two groups participating in the study.

Table 1. Example of the evaluation guide on teaching numbers.

Math Area	Range
Identify the numbers N	1–10
Write the numbers N in an understandable way	1–10
Read the numbers N, without repeating the series, example, 9, 2, 6, 8, 1 . . . unstable order	1–10
Recognizes the number of objects up to 9	1–10
Repeat the names of the numbers in the same order, that is, the order of the numerical series is always the same, 1, 2, 3, 4, 5 . . . stable order	1–10
Make a collection count to 9	1–10
It uses the irrelevance of the order, the order in which the elements are counted does not influence to determine the objects that a collection has.	1–10
Identify the numbers N	1–10

Table 2 presents the results obtained from the group of children who learned N numbers with the use of a traditional education model. To improve the visibility of the results tables, the criteria are replaced by short names such as:

- C1 = Identifies the numbers N.
- C2 = Write the numbers N in an understandable way.
- C3 = Read N numbers.
- C4 = Recognizes the number of objects up to 9.
- C5 = Repeat the names of the numbers in the same order; that is, the order of the numerical series is always the same, 1, 2, 3 . . . stable order.
- C6 = Perform a collection count to 9.
- C7 = Uses the irrelevance of the order; the order in which the elements are counted does not influence the determination of the objects that a collection has.

Table 2. Ranges and averages of the evaluation of the teaching of the numbers N, using a traditional teaching model.

Math Area	Ind. 1	Ind. 2	Ind. 3	Ind. 4	Ind. 5	Ind. 6	Average
C1	8	9	3	2	5	6	5.5
C2	3	10	8	7	5	5	6.3
C3	7	7	4	3	7	8	6.0
C4	3	7	8	10	5	9	7.0
C5	4	7	3	2	7	7	5.0
C6	4	6	10	8	4	6	6.3
C7	9	10	4	5	6	9	7.2
Average Total	5.4	8.0	5.7	5.3	5.6	7.1	6.2

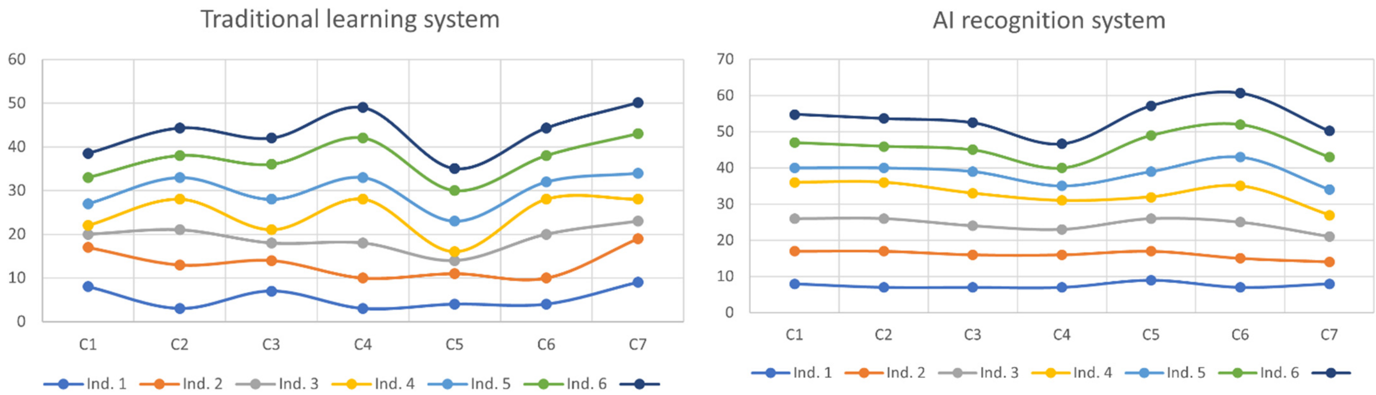
The results found in these data correspond to a group of six children whose personal data are not included in the study for security reasons and have been assigned a referential name. This referential name is "Ind. of Individual" accompanied by a number to identify the children. Each of the values is those given by the tutor to the skills demonstrated by the preschool children in number management. In the last column as a row, the total average has been included. This value serves as a reference and information for the tutor to easily identify the criterion to be reinforced. For example, the table shows that the lowest averages are C1 and C5; therefore, the tutor must work on activities that allow the child to properly identify the N numbers; likewise, she must work on the order of the numbers, so that preschool children can count from 1 to 9, maintaining a stable order.

Table 3 presents the results obtained from the children who worked on the teaching numbers using the AI system. This table shows that the averages have improved concerning the traditional teaching model; however, in certain evaluation criteria, there is no significant difference between models. For example, in C4 and C7, where the recognition of the number of objects up to nine, is better in the traditional teaching group. In the use of order irrelevance (the order in which the items are counted does not influence the determination of the objects in a collection), the two groups have a similar level. In the rest of the criteria, there is a better performance of the preschoolers in the handling of numbers, who used the AI recognition system adequately motivates the teaching; however, it is necessary to adjust the data entry and presentation of the results system to improve the teaching.

Table 3. Ranges and averages of the evaluation of the teaching of the numbers N, using a teaching model through an AI recognition system.

Math Area	Ind. 1	Ind. 2	Ind. 3	Ind. 4	Ind. 5	Ind. 6	Average
C1	8	9	9	10	4	7	7.8
C2	7	10	9	10	4	6	7.7
C3	7	9	8	9	6	6	7.5
C4	7	9	7	8	4	5	6.7
C5	9	8	9	6	7	10	8.2
C6	7	8	10	10	8	9	8.7
C7	8	6	7	6	7	9	7.2
Average Total	7.6	8.4	8.4	8.4	5.7	7.4	7.7

Figure 4 shows the comparison of the results of the evaluation guide; part (a) refers to the group that remained in a traditional teaching model and part (b) contains the results of the application of the recognition system with AI. The graphs allow us to establish the differences between the use of AI in teaching versus traditional teaching. The X-axis shows the evaluation criteria used in the teaching of natural numbers. The Y-axis represents the evaluation scale by criteria; these are out of 10, however, as each preschool child is represented on separate lines, the scale is adjusted from 0 to 60; this is reference data when replicating this method; the factor will be above 10 will be shown. The trend lines are seven, of which six correspond to the children and the line painted in dark blue is the average learning of the group. In this context, the group in which the traditional learning system was applied presents a very marked irregularity, unlike the group that used the AI system, which presents a more stable line. In graph (a), the strong point for several of the children is C4; the opposite occurs with the AI system, where this criterion is penalized, and a certain drop-in in teaching is noted. This is mainly because the system was configured so that the numbers appear randomly and the child replicates them, without giving priority to the recognition of the amount that each number means. This deficiency is fully adjustable since the system can randomly display several objects that the child must identify and represent the number for the AI system to start the training and recognition process.



(**a**) (**b**)

Figure 4. Comparison between a traditional education model and a model that uses an AI recognition system: (**a**) traditional number teaching model; (**b**) teaching numbers with a recognition system with the use of AI.

4. Discussion

Teaching preschool children is very important; therefore, both parents and children's centers are looking for new methods and educational models that allow children to acquire the ability to learn in an effective and motivating way. Several studies reviewed refer to the importance of interaction with tutors and parents to establish in children the necessary bonds that favor their motivation and capacity to generate knowledge. However, it is currently important to include ICT in teaching, as they are necessary tools in an increasingly digitalized world [31,32]. Moreover, during the pandemic, personal interaction was one of the missing points at all educational levels [33,34].

Similar works include gamification as a component that provides motivation and interest in preschool children. This concept is very valid considering that, due to the age of the children, it is necessary to establish a mechanism that improves their concentration and interest in teaching a subject. In gamification, it is possible to use several tools that may include a reward model, creating a competitive environment for the child, and achieving the ultimate goal, which is motivation [15]. Gamification gives children the opportunity to collaborate and develop valuable academic and life skills; however, teaching through gamification is not without difficulties, e.g., the expected results are not guaranteed, and the difficulty of supporting the needs of infants when their ideas are very creative and difficult to understand. Another difficulty is when documenting the teaching through photos, videos, etc., and converting this material into visible products [35]. In addition to ensuring that the entire team has a solid understanding of play-based teaching, a positive mindset, and a willingness to change their practices.

In this work, the concept of gamification is considered since the mechanics of the system behaves as a teaching game of N numbers, where the child assumes the role of a tutor and trains the system by presenting the different numbers. The system takes the number as an image and trains its artificial neuron to recognize it and present the possible outcome [36,37]. By placing children in the role of tutor, the level of teaching increases since teaching something automatically generates in people an increase in their ability to learn. The results obtained from the application reveal the improvement in N-number handling by using the proposed system. Each phase of the architecture ensures the development of writing, identifying, and reading numbers for both preschoolers and the system. In the first phase of the design, a randomized process was implemented where the system presents a number to be replicated by the child. Upon taking the image of the written number, the system must meet the appropriate weights that allow it to recognize the number. If this process is unsuccessful, the system repeats the process until its training base allows it to generate an optimal result. To keep preschool children motivated and to keep the system in perfect use, the supervision and help of a tutor in charge of the subject are recommended.

Several techniques contribute to the integration of ICT in society; among these, the Markov decision process was also reviewed. This process is used in deep reinforcement learning and can conclude through a sequence of random states that has the Markov property. This method has not been compared with our recognition system; on the contrary, in future work, this process will be integrated into the method to improve the system's decisions, using a sequence of random states.

The group considered for this study is small, which did not allow to work in a granular way in the adjustment of the system and to verify that it suits the needs of each child. In addition, several of the preschool children who used the system have been found to have problems with the pronunciation of vocabulary. This affects the system since it needs a clear confirmation of the answer. As a solution, a process has been put in place that allows the system to recognize certain letters. For example, the letter "R", this letter of the Spanish language is one of the letters that take the longest time in its phonetics. This update will be presented in future work that includes the input to the system of other topics, such as the identification of vowels and consonants.

In the results, several events stand out in the comparison between the traditional learning system and the learning using the recognition system. In the first instance, it is found that in the learning of numbers using the traditional system, there is a contraction when evaluating criterion C5 (repeating the names of the numbers in the same order, that is, the order of the numerical series is always the same, 1, 2, 3... stable order), the stable order, according to the tutors, depends on the repetition of the numbers in series. This process in traditional learning is performed with songs; however, by eliminating this element, children forget which number follows. This criterion, on the contrary, in the parallel using the recognition system is easily overcome; it changes the method of repetition; this is because, in the beginning, the system is trained with sequential numbers, for example, 1, 2, 3, etc., this allowed the children not only to repeat the number several times but also to recognize it. Since the system, in the beginning, did not recognize the numbers written by the student, it became a process of improvement. In addition, the expert tutors in the children's learning center assumed that the variation is within the established ranges and that the repetition of the numbers in stable order takes more than five months and that the work should be shared at home, through additional tasks. Another criterion for analysis is the various existing in criterion four (recognize the number of objects up to 9); these results are mainly because, in the first weeks of implementation of the recognition system, the element of recognition was not integrated into it; therefore, the children identified the numbers and wrote them in a more agile way than in traditional learning. However, not having a complement by which they understand the quantity factor resulted in a deficiency of the system. This was corrected in the fourth week of the application of the system, but the results show that it is necessary to include all the components of the system from the beginning of the learning of numbers.

5. Conclusions

In applying the method, some components have been identified that need to be improved at a later stage of the proposal. For example, it is important to have good lighting and a good focus on the webcam for better image capture. These factors have been identified as elements that are detrimental to the correct capture of the characters. This means that no matter how good the results are with the algorithms used, if the start of the process is incorrect, the results will be incorrect as well. In the image binarization process, it is important to establish an ideal threshold value that properly captures the characters on the board. Obtaining the ideal value of the histogram of the captured image has the particularity that it is adaptable according to each photo captured from the forms. For the training of the neural network, the weights necessary to subsequently perform the recognition have been established. Therefore, it is not necessary to train every time a number is to be recognized, which implies a low computational cost.

Preschool education depends on tutors, especially because of the age of the children who attend this level of education. Children create bonds of trust with their tutors, and this is reflected in the motivation they feel about learning and carrying out their activities. The proposed system does not seek to replace the tutor; on the contrary, it seeks to create an environment where the tutor becomes an educational support tool.

According to the results obtained, it has been identified that the number recognition system improves the synchronization and identification of numbers by preschool children and even helps to improve their motor skills in writing numbers. However, the system needs to be adjusted for preschoolers to recognize numbers based on the quantity they represent. This adjustment will be made in future work; in addition, it is proposed to include topics such as vowels and consonants.

The effectiveness of prototype recognition will depend on several characteristics of the training corpus. These include image quality, illumination quality, handwriting quality, and other non-method-related issues. Similar to the hardware and environment; therefore, it is necessary to emphasize the collection of samples (images) to create a robust corpus to contribute to the training database. Through the tests carried out in the use of the method, the effectiveness of the recognition was proven, and it is possible to work with this system as a technique that contributes to the teaching of other subjects, thus opening a range of possibilities for the use of ICT in the classroom, regardless of the educational level.

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

Appendix A

Appendix A.1. AI Processing

In the AI processing phase, the matrix uses Python for the implementation of the algorithm, starting with changing the image matrix to a grayscale. Next, we proceed to binarization, which consists of transforming a digital image into black and white in such a way that it retains the essential properties of the image. Figure A1 presents the process required for binarization [38,39]. In it, the histogram of the matrix is calculated and stored in a column vector with the position indicating the hue and its pixel value. The next step is to calculate the probability of the ones that are represented by r and contain values from 0 to 255 in a row vector. To achieve this, each value in the vector is divided by the total number of pixels. With the results of this vector, the mean and variance are calculated, which are used to determine the ideal threshold value that identifies the dark pixels in the image; For best results, the numbers written by the children on the board should be performed with black markers [40]. The pixel values are divided by the threshold value and to this, the sign operation is applied, where:

- If threshold value > 0 it is 1.
- If threshold value = 0 it is 0.
- If threshold value < 0 it is −1.

The result of the operation is multiplied by 255 to obtain the new matrix with pixel values from 0 to 255. The result of this calculation allows for the display of black characters and white backgrounds.

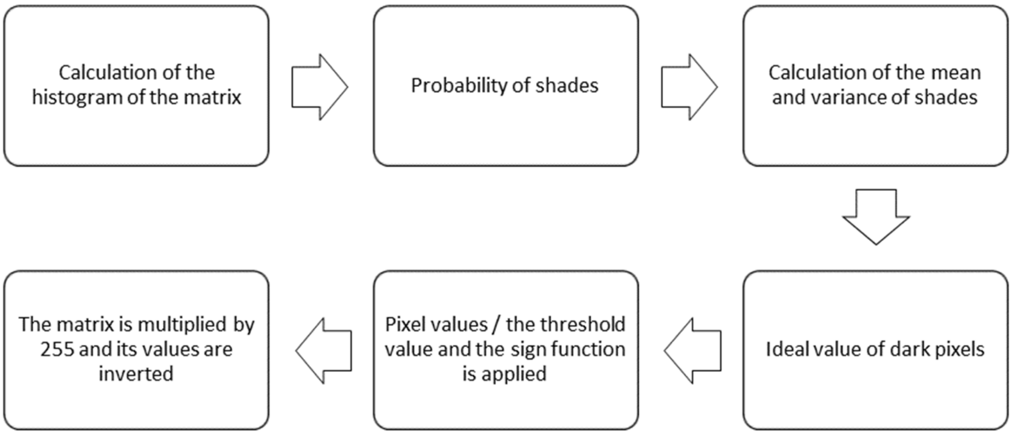

Figure A1. Phases for the binarization of the training images of the system.

Appendix A.1.1. Image Segmentation

The goal of segmentation is to divide an image into parts or regions; the division into parts is based on the characteristics of the pixels in the image. For example, one way to find regions in an image is to look for sharp discontinuities in the pixel values, which indicates the presence of edges [41]. Segmentation algorithms have two basic properties; an algorithm can be based on one of these basic properties of the gray level values, the discontinuity or the similarity between the gray levels of neighboring pixels [42]. Discontinuity divides the image based on abrupt gray level changes for a single point, line, and edge detection. Similarity divides the image based on finding areas having similar values according to predetermined criteria such as regional growth and thresholding [43,44].

To process the algorithm in Python that was created in the late 1980s by Guido van Rossum at the Center for Mathematics and Informatics in the Netherlands, the OTSU threshold is used, which eliminates the result of over-segmentation due to noise or any other irregularity in the image, and it is implemented with OpenCV. OpenCV is a free computer vision library originally developed by Intel in January 1999. Figure A2 shows the output of the image transformed by the threshold operation where the noise it contains in each stage of the transformation is observed. To remove any white noise in the image, it is possible to use morphological closure and bring the object to the foreground. Image segmentation is a fundamental process in image recognition, both for image compression and the study of its content. This is based on the partition of the image into separate regions that correspond to representations of different objects; in this work, these objects are numbers. With segmentation or thresholding, when capturing the image of a number, it is divided into regions based on intensity values; these allow an object to be identified or extracted from its background based on the distribution of gray levels or the texture of the image of the number.

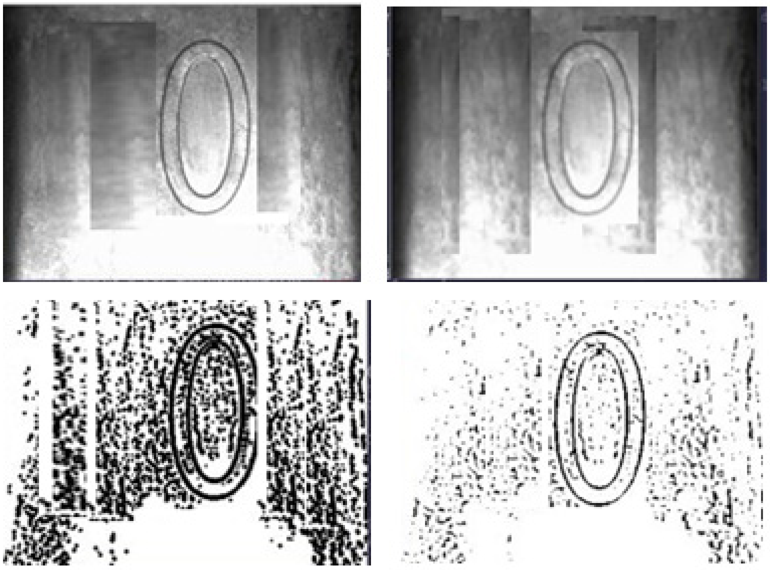

Figure A2. Segmentation applied to the images captured by the recognition system.

In the figure after image segmentation, the objects present in the background, where the slate is located, have been separated. In addition to other objects, it is possible to create spots using the blackboard or even other unwanted images within the ID to be captured by the camera focus. Therefore, by applying segmentation, it is possible to identify which pixels belong to which elements of a photograph. For this purpose, using OTSU, it is possible to find a rough estimate of the objects in the image; subsequently, small sections of white noise are removed. In the lower-left frame, the results of the process are presented, and in the lower-right frame, the objects are dilated, ensuring that any background regions are part of the background and not noise.

Appendix A.1.2. Segment Rotation

There are several problems in image recognition, especially when applied to an environment exposed to motion, light, and other factors. This results in several segments of the number not being straight. To solve this problem, the segment matrix can be rotated by capturing the pixels with the values found in the first and last columns of the segment. Figure A3 shows the matrix of the tilted section with the obtained positions. Subsequently, the column of the first black pixel of the row is captured and if this value is greater than half of the total columns, then the row of the first black pixel of the first column is captured; otherwise, the row of the first pixel is captured in black in the last column. The segmented matrix is rotated counterclockwise, regardless of the calculated angle. It is important to consider that when performing the rotation process, local interpolation is applied, so when rotating its size, the matrix must be re-binarized with the new pixel values created by the interpolation [45]. In addition, the threshold value is recalculated to capture lighter pixels in the matrix; this matrix is created from the following code:

- img = cv2.imread(num.png).
- rows, cols, ch = img.shape.
- pts1 = np.float32([[100, 400], [400, 100], [100, 100]]).
- pts2 = np.float32([[50, 300], [400, 200], [80, 150]]).
- M = cv2.getAffineTransform(pts1, pts2).
- dst = cv2.warpAffine(img, M, (cols, rows)).

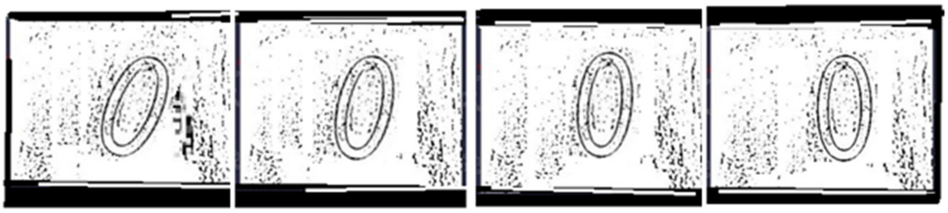

Figure A3. Application of the rotated segments algorithm to improve image quality.

When rotating images, the edges of the image are usually cut off, as shown in the example in the figure. When the image is rotated with a larger angle, it means that part of the image is lost during the process. This is not a bug in OpenCV, but it is how the functions are designed. To solve this problem, it is possible to use several coexistence functions with OpenCV. The image captured in the image is made up of four quadrants, which indicate the different angles to which the figure was subjected for the rotation process. To move from the initial quadrant, it is necessary to find its rotation matrix; for this, the function getRotationMatrix2D() of OpenCV is used. In the function, the first argument is the center of the image by which the image is rotated. The second argument is the rotation angle, and the third argument is the scale of the image. If the scale is less than one, the image will become smaller than the original image. The image will be scaled or enlarged if the scale is a positive number; if the scale is 1, the image will not be scaled. The first argument of the warpAffine() function is the image to rotate, the second argument is the rotation matrix, and the third argument is the size of the output image. For example, the figure shows the rotation of the image around its center, for which the following code is added:

- image = cv2.imread("num.jpg").
- (h, w) = image.shape[:2].
- center = (w/2, h/2).
- angle = 15.
- scale = 1.
- M = cv2.getRotationMatrix2D(center, angle, scale).
- rotated = cv2.warpAffine(image, M, (w, h)).
- cv2.imshow('original Image', image).
- cv2.imshow('Rotated Image', rotated).
- cv2.waitKey(0).
- cv2.destroyAllWindows().

Applying the above code, the shape method is used to find the length and width of the given image. Then the center of the image is calculated by taking half of the length and width. You can change the center, angle, and scale value to obtain the desired result.

Appendix A.1.3. Image Recognition

Once the most important features of the image are obtained, the corresponding character is determined by applying a neural network. Neural networks with data mining schemes mimic the architecture of human intelligence [46]. One way to represent it is by using basic units known as neurons; these receive inputs that are multiplied by weights and present outputs with a fitting function that depends on the sum of the previous outputs [47]. Neural networks are one of the most widely used techniques for character recognition, since, properly trained, they can identify the characters in the images captured by the system without presenting major drawbacks. The scheme of the neural network used is represented in Figure A4, it consists of three layers that are responsible for a specific activity, and the input layer supports data from n inputs [48]. It also incorporates one or more hidden layers and an output layer; with this layered architecture, the network learns by examining individual records and generates a prediction for each of them, adjusting the weights when it makes an erroneous weight [49,50]. This process is cyclic and, at each repetition, the network improves its predictions until it reaches the expected stopping criteria.

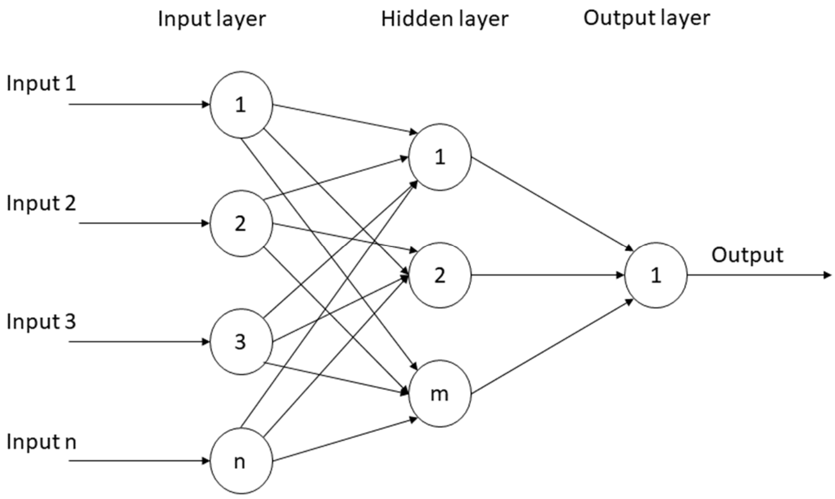

Figure A4. Scheme of an artificial neural network with three layers.

To train the neural network, it is necessary to adjust the input weights so that the results of the output layer match the known data as closely as possible. In Figure A5, a simplified example of the training process of a network to identify the number "8" is presented. The thickness of each arrow represents the weights that the input has in the neural network; as the weights are adjusted, the error decreases. To enter a neural network and for it to be able to detect the numbers of any image, it will be necessary to use many images that number "8" labeled as "1" and many images that are not, labeled as "2", which include as much variability as possible. Since the network has many images, it will be able to adjust its parameters to satisfy all images, thus accurately extracting features that identify the presence of a number in the image.

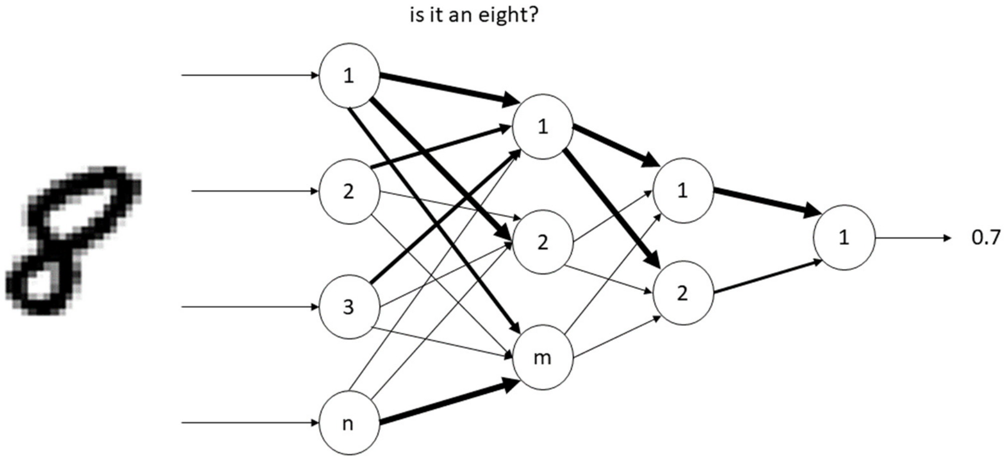

Figure A5. Inputs and weights of an artificial neural network for the identification of a number; the thick lines represent the weights with the greatest influence on forming a conclusion.

Appendix A.2. Presentation of the Results

Figure A6 shows the process for the presentation of the results; once the AI system identifies the number, it presents it on the screen and waits for the user's confirmation. The result depends on the image captured on the whiteboard if the number is the closest to an image that is part of the system's knowledge base. The answer, in addition to being presented on the monitor, can be read by the system, thus improving the interaction with the preschoolers. For example, the type of answer corresponds to the following text:

- Is it number two?
- Is it the number eight?
- Is it number five?

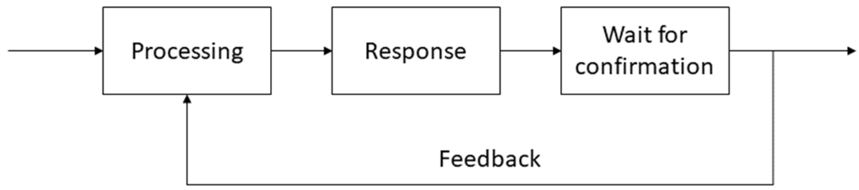

Figure A6. Scheme for the presentation of results and confirmation of successes or failures.

Appendix A.3. Manual Input

This phase corresponds to the confirmation that the system expects after presenting the result of the image processing. If the child or guardian determines that the number identified by the system is correct, one of them must confirm the result. To perform this, the system requires a click of a button or a voice notification. Figure A7 shows the interaction between the system and the child or guardian; the confirmation can be given by one of the options since there will be cases in which the computer does not have a microphone, which will force us to keep the confirmation through the button. If all components of the system are present, the physical response can be ignored, and the voice confirmation can simply be made.

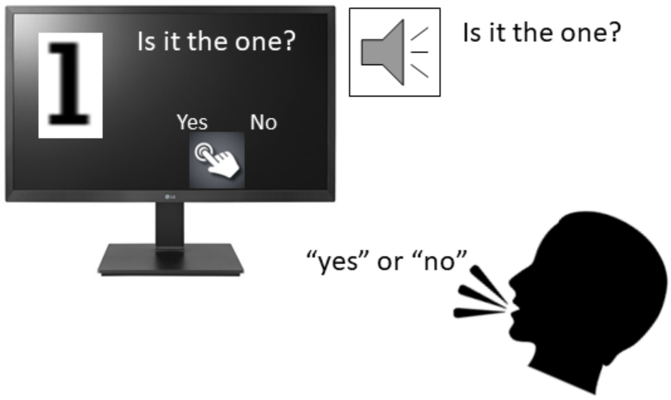

Figure A7. Interaction between the preschool children and the recognition system for the confirmation of answers.

Appendix A.4. Evaluation, Storage, and Adjustment of Weights

Starting from the evaluation phase, the process becomes cyclical, so this section describes the phases of the flowchart. The evaluation starts when the system receives the confirmation response before the identification result of the first image. If the answer is positive, the system automatically continues the game and randomly presents another number and starts the recognition process. If the confirmation to the number given as a result is negative, the system makes a new attempt to recognize the image; therefore, it stores the image, adjusts the weights, and presents the new result; in this process, the response given can be the same as the first try. Once the process is finished, the system presents the new result and repeats the confirmation process. If, in this new attempt with the adjustment of the weights, the system recognizes the number correctly, it continues with the next phase of the process. If the answer is negative again, the system asks the user to indicate which number is represented on the board, since they only have two attempts to recognize the number. The interaction text between the presentation of the result and the confirmation is as follows:

- System: it is a two?
- Preschool children or tutor: yes, it is a two.

For a negative response, the format is as follows:

- System: it is a four?
- Preschool children or guardian: no.
- System: what number is it?
- Preschool children or tutor: it is a two.
- Once the user indicates to the system which is the number that is present on the board, the system takes this information, adds an identifier linked to the image, and stores it in the database. With these new parameters, it adjusts the training weights and tries again to identify the image that contains the number, and this process is carried out until the weights and the training generate the expected output. If the children confirm that the result is correct this time, the system requests confirmation to continue with the game or ends the session. The interaction format is as follows:
- System: it is a four?
- Preschool children or guardian: yes.
- System: are we still teaching?
- Preschool children or guardian: "yes" or "no".

References

1. Hinostroza, J.E. New challenges for ICT in education policies in developing countries: The need to account for the widespread use of ICT for teaching and learning outside the school. In *ICT-Supported Innovations in Small Countries and Developing Regions*; Springer: Cham, Switzerland, 2018; pp. 99–119.
2. Popoola, S.I.; Atayero, A.A.; Okanlawon, T.T.; Omopariola, B.I.; Takpor, O.A. Smart campus: Data on energy consumption in an ICT-driven university. *Data Brief* **2018**, *16*, 780–793. [CrossRef] [PubMed]
3. Villegas-Ch., W.; García-Ortiz, J.; Román-Cañizares, M.; Sánchez-Viteri, S. Proposal of a remote education model with the integration of an ICT architecture to improve learning management. *PeerJ Comput. Sci.* **2021**, *7*, e781. [CrossRef] [PubMed]
4. Sidpra, J.; Gaier, C.; Reddy, N.; Kumar, N.; Mirsky, D.; Mankad, K. Sustaining education in the age of COVID-19: A survey of synchronous web-based platforms. *Quant. Imaging Med. Surg.* **2020**, *10*, 1422–1427. [CrossRef] [PubMed]
5. Gupta, S.; Jawanda, M.K. The impacts of COVID-19 on children. *Acta Paediatr. Int. J. Paediatr.* **2020**, *109*, 2181–2183. [CrossRef] [PubMed]
6. Rios-Campos, C.; Campos, P.R.; Delgado, F.C.; Ramírez, I.M.; Hubeck, J.A.; Fernández, C.J.; Vega, Y.C.; Méndez, M.C. COVID-19 and universities in Latin America. *S. Fla. J. Dev.* **2021**, *2*, 577–585. [CrossRef]
7. Bahasoan, A.N.; Ayuandiani, W.; Mukhram, M.; Rahmat, A. Effectiveness of online learning in pandemic COVID-19. *Int. J. Sci. Technol. Manag.* **2020**, *1*, 100–106. [CrossRef]
8. Kerckaert, S.; Vanderlinde, R.; van Braak, J. The role of ICT in early childhood education: Scale development and research on ICT use and influencing factors. *Eur. Early Child. Educ. Res. J.* **2015**, *23*, 183–199. [CrossRef]
9. Pohradský, P.; Londák, J.; Čačíková, M. Application of ICT in Pre-School Education. In Proceedings of the Proceedings Elmar–International Symposium Electronics in Marine, Zadar, Croatia, 15–17 September 2010.
10. Plowman, L.; Christine, S.; Susan, D.; Sime, D. Supporting learning with ICT in pre-school settings. *Teach. Learn. Res. Programme* **2006**. Available online: https://www.semanticscholar.org/paper/Supporting-learning-with-ICT-in-pre-school-settings-Plowman-Stephen/bc375589aa22db27a07585ae80250e64bf0d6fee (accessed on 30 August 2022).
11. Huda, M.; Maseleno, A.; Shahrill, M.; Jasmi, K.A.; Mustari, I.; Basiron, B. Exploring adaptive teaching competencies in big data era. *Int. J. Emerg. Technol. Learn.* **2017**, *12*, 68–83. [CrossRef]
12. Hill, J.R.; Hannafin, M.J. Teaching and learning in digital environments: The resurgence of resource-based learning. *Educ. Technol. Res. Dev.* **2001**, *49*, 37–52. [CrossRef]
13. Amory, A.; Seagram, R. Educational game models: Conceptualization and evaluation. *S. Afr. J. High. Educ.* **2004**, *17*, 206–217. [CrossRef]
14. Huang, Y.M.; Liang, T.H.; Su, Y.N.; Chen, N.S. Empowering personalized learning with an interactive e-book learning system for elementary school students. *Educ. Technol. Res. Dev.* **2012**, *60*, 703–722. [CrossRef]
15. Stroeva, O.A.; Zviagintceva, Y.; Tokmakova, E.; Petrukhina, E.; Polyakova, O. Application of remote technologies in education. *Int. J. Educ. Manag.* **2019**, *33*, 503–510. [CrossRef]
16. Fernández-Gutiérrez, M.; Gimenez, G.; Calero, J. Is the use of ICT in education leading to higher student outcomes? Analysis from the Spanish autonomous communities. *Comput. Educ.* **2020**, *157*, 103969. [CrossRef]

17. Valtonen, T.; Kukkonen, J.; Kontkanen, S.; Mäkitalo-Siegl, K.; Sointu, E. Differences in pre-service teachers' knowledge and readiness to use ICT in education. *J. Comput. Assist. Learn.* **2018**, *34*, 174–182. [CrossRef]
18. Fedorenko, E.H.; Velychko, V.Y.; Stopkin, A.V.; Chorna, A.V. Informatization of education as a pledge of the existence and development of a modern higher education. *CTE Workshop Proc.* **2019**, *6*, 20–32. [CrossRef]
19. Hernández, J.; Mousalli, G.; Rivas, F. Learning difficulties diagnosis for children's basic education using expert systems. *WSEAS Trans. Inf. Sci. Appl.* **2009**, *6*, 1777–1792.
20. Ouherrou, N.; Elhammoumi, O.; Benmarrakchi, F.; El Kafi, J. Comparative study on emotions analysis from facial expressions in children with and without learning disabilities in virtual learning environment. *Educ. Inf. Technol.* **2019**, *24*, 1777–1792. [CrossRef]
21. Zhou, C.; Li, S. Application of Children Artificial Intelligence Science Popularization Books Based on Augmented Reality Technology. In Proceedings of the 2021 International Symposium on Artificial Intelligence and Its Application on Media, ISAIAM 2021, Xi'an, China, 21–23 May 2021.
22. Vinter, A.; Bard, P.; Lukowski-Duplessy, H.; Poulin-Charronnat, B. A Comparison of the Impact of Digital Games Eliciting Explicit and Implicit Learning Processes in Preschoolers. *Int. J. Child Comput. Interact.* 2022; *in press*. [CrossRef]
23. Xiong, Z.; Liu, Q.; Huang, X. The Influence of digital educational games on preschool children's creative thinking. *Comput. Educ.* **2022**, *189*, 104578. [CrossRef]
24. Kangas, M. Creative and playful learning: Learning through game co-creation and games in a playful learning environment. *Think Ski. Creat.* **2010**, *5*, 1–15. [CrossRef]
25. Wang, Z. Theory of mind and children's understanding of teaching and learning during early childhood. *Cogent Educ.* **2015**, *2*, 1011973. [CrossRef]
26. Ziv, M.; Solomon, A.; Strauss, S.; Frye, D. Relations between the development of teaching and theory of mind in early childhood. *J. Cogn. Dev.* **2016**, *17*, 264–284. [CrossRef]
27. Liu, B.; Jiao, S. Analysis of Supply and Demand and Behavioral Intention of Children's Programming Education Market: Taking Beijing as an Example. In Proceedings of the 2020 International Conference on Modern Education and Information Management, ICMEIM 2020, Dalian, China, 25–27 September 2020.
28. Henry, J.; Hernalesteen, A.; Collard, A.S. Teaching Artificial Intelligence to K-12 Through a Role-Playing Game Questioning the Intelligence Concept. *KI-Künstliche Intelligenz* **2021**, *35*, 171–179. [CrossRef]
29. Zacharis, N.Z. Predicting student academic performance in blended learning using artificial neural networks. *Int. J. Artif. Intell. Appl.* **2016**, *7*, 17–29. [CrossRef]
30. Gràcia, X.G.; Sancho-Gil, J.M. Artificial Intelligence in Education: Big Data, Black Boxes, and Technological Solutionism. *Seminar.net.* **2021**, *12*, 2. [CrossRef]
31. Lopez-Bernal, D.; Balderas, D.; Ponce, P.; Molina, A. Education 4.0: Teaching the basics of KNN, LDA and simple perceptron algorithms for binary classification problems. *Futur. Internet* **2021**, *13*, 193. [CrossRef]
32. Adukia, A.; Eble, A.; Harrison, E.; Runesha, H.B.; Szasz, T. What we teach about race and gender: Representation in images and text of children's books. *SSRN Electron. J.* **2021**. [CrossRef]
33. Rosique, F.; Losilla, F.; Navarro, P.J. Using artificial vision for measuring the range of motion. *IEEE Lat. Am. Trans.* **2021**, *19*, 1129–1136. [CrossRef]
34. Villegas-Ch, W.; Palacios-Pacheco, X.; Buenaño-Fernandez, D.; Luján-Mora, S. Comprehensive learning system based on the analysis of data and the recommendation of activities in a distance education environment. *Int. J. Eng. Educ.* **2019**, *35*, 1316–1325.
35. Sebastian, S.; Puthiyidam, J.J. Evaluating students performance by artificial neural network using WEKA. *Int. J. Comput. Appl.* **2015**, *119*, 36–39. [CrossRef]
36. Cong, L.; Ding, S.; Wang, L.; Zhang, A.; Jia, W. Image segmentation algorithm based on superpixel clustering. *IET Image Process.* **2018**, *12*, 2030–2035. [CrossRef]
37. Udupa, J.K.; LeBlanc, V.R.; Zhuge, Y.; Imielinska, C.; Schmidt, H.; Currie, L.M.; Hirsch, B.E.; Woodburn, J. A framework for evaluating image segmentation algorithms. *Comput. Med. Imaging Graph.* **2006**, *30*, 75–87. [CrossRef] [PubMed]
38. Aguiar, G.J.; Mantovani, R.G.; Mastelini, S.M.; de Carvalho, A.C.P.F.L.; Campos, G.F.C.; Junior, S.B. A meta-learning approach for selecting image segmentation algorithm. *Pattern Recognit. Lett.* **2019**, *128*, 480–487. [CrossRef]
39. Selva Kumar, S.; Krishna Sandeep Reddy, G.; Rajathilagam, B. Comparison of image segmentation algorithms. *Int. J. Appl. Eng. Res.* **2015**, *10*, 336–367.
40. Haritosh, A.; Ralekar, C.; Kaur, T.; Gandhi, T.K. Human Visual Learning Inspired Effective Training Methods. In Proceedings of the 2019 IEEE 16th India Council International Conference, INDICON 2019-Symposium Proceedings, Rajkot, India, 13–15 December 2019.
41. Villegas-Ch, W.; García-Ortiz, J.; Mullo-Ca, K.; Sánchez-Viteri, S.; Roman-Cañizares, M. Implementation of a virtual assistant for the academic management of a university with the use of artificial intelligence. *Future Internet* **2021**, *13*, 97. [CrossRef]
42. Gondal, A.U.; Sadiq, M.I.; Ali, T.; Irfan, M.; Shaf, A.; Aamir, M.; Shoaib, M.; Glowacz, A.; Tadeusiewicz, R.; Kantoch, E. Real time multipurpose smart waste classification model for efficient recycling in smart cities using multilayer convolutional neural network and perceptron. *Sensors* **2021**, *21*, 4916. [CrossRef]
43. Chen, G.; Wang, H.; Zheng, J. Application of Image Recognition Technology in Garbage Classification Education Platform. In Proceedings of the 2019 5th International Conference on Control, Automation and Robotics, ICCAR 2019, Beijing, China, 19–22 April 2019.

44. Wiley, D. On the Sustainability of Open Educational Resource Initiatives in Higher Education. In Proceedings of the OECD's Centre for Educational Research and Innovation (CERI), Barcelona, Spain, April 2007; p. 21.
45. Ellaway, R.H.; Pusic, M.V.; Galbraith, R.M.; Cameron, T. Developing the role of big data and analytics in health professional education. *Med. Teach.* **2014**, *36*, 216–222. [CrossRef]
46. Mathew, R.B.; Varghese, S.; Joy, S.E.; Alex, S.S. Chatbot for Disease Prediction and Treatment Recommendation Using Machine Learning. In Proceedings of the International Conference on Trends in Electronics and Informatics, ICOEI 2019, IEEE, Tirunelveli, India, 23–25 April 2019; pp. 851–856.
47. Villegas-ch, W.; Arias-navarrete, A.; Palacios-pacheco, X. Proposal of an architecture for the integration of a chatbot with artificial intelligence in a smart campus for the improvement of learning. *Sustainability* **2020**, *12*, 1500. [CrossRef]
48. Dukhanina, L.N.; Maximenko, A.A. Problems of the implementation of artificial intelligence in education. *Perspect. Sci. Educ.* **2020**, *46*, 23–35. [CrossRef]
49. Hu, B. English Listening teaching model in flipped classroom based on artificial intelligence fusion control algorithm. *Math. Probl. Eng.* **2021**, *2021*, 6005359. [CrossRef]
50. Topin, L.O.; Barwaldt, R.; Ribeiro, L.M.I.; Spidola, D.; Freitas, A.L.C.d.; Pias, M.; Torres, M.; Sartori, J. Towards Machine Learning for Enhanced Maths Teaching to the Blind. In Proceedings of the Proceedings-Frontiers in Education Conference, FIE, Covington, KY, USA, 16–19 October 2019; Volume 2019.