Virtual Reality and Haptic Devices Applied in the System of Teaching Learning with Children of Early Education Age

Marco Pilatásig(✉), Emily Tobar(✉), Lissette Paredes(✉), Zulia Sánches(✉), and Grace Naranjo(✉)

Universidad de Las Fuerzas Armadas ESPE, Sangolquí, Ecuador
{mapilatagsig,ektobar,mlparedes2}@espe.edu.ec,
zuliamaria@hotmail.com, gracenaranjo14@gmail.com

Abstract. The aim of this work is to make known the possible applicability and usefulness of new technologies such as virtual reality and haptic devices to improve the education of children of pre-school age. The aim is not only to integrate these new technologies into pre-school education but also to evaluate the improvements that this would introduce, for which a system has been designed that includes a computer and a haptic device whose shape resembles a pencil and its use is very similar to a mouse. Several virtual interfaces have been designed in which different environments are presented where the child must perform tasks designated by the teacher; the child interacts with these interfaces with the help of the haptic device that also has the ability to feedback forces that will prevent the child from performing the task incorrectly. The interfaces are designed as games to please the child, for this 3D software is used, the haptic device is a Geomagic Touch and the tasks are structures by the teacher, according to the age and skill that is intended to improve in the child. The proposals and results of two previous works carried out by the authors are presented.

Keywords: Early education · Virtual reality · Haptic devices

1 Introduction

Education in the world is a very decisive factor for the development of countries, therefore it is very important that the teaching-learning process be improved; in addition, it should be considered that in initial education the child learns based on games and begins to develop his abilities.

According to studies carried out, human intelligence will have better results if early stimulation is carried out; therefore, at this stage, the use of any resource should be focused, especially the use of new technologies applied in education to achieve the proposed objectives [1].

Education depends on many actors, however, in pre-school education, the participation of the family is a determining factor and the teacher must adequately structure the

M. Botto-Tobar et al. (Eds.): ICAT 2020, CCIS 1388, pp. 33–43, 2021.
https://doi.org/10.1007/978-3-030-71503-8_3

teaching-learning process, therefore it is essential to use the greatest amount of resources [2–4].

In Ecuador, attention deficit, hyperactivity, learning difficulties as well as a low level of reasoning are problems that affect children's learning and can be reduced by applying other teaching methods in which new technologies are immersed, such as computers, tablets, haptic devices, etc. [5, 6].

The new technologies with their great diversity, being attractive and attracting the attention of the child, can improve his concentration and his reasoning capacity, especially if they are applied as tools for playful games. In Ecuador, the Early Education Curriculum uses play as a tool for entertaining and meaningful learning. [7–9].

The computer has been widely used in education and now new devices such as phones and iPods can be included as teaching aids, although their misuse creates serious problems, a correct application can represent a breakthrough when it comes to encouraging the child to eager to learn, in these devices can use virtual reality and augmented reality, creating 3D environments that provide the ability to educate in an entertaining and enjoyable way, for interaction with developed environments, other devices can be used, ranging from a simple mouse to other haptic devices that present feedback of forces and integrate sensations that the child finds pleasant and at the same time can give indications for the child to correctly perform the task assigned, such as sensations that prevent him from improperly tracing a letter. [10–16].

Virtual reality (VR) allows the creation of environments with very realistic, dynamic and entertaining images and sound, where the child can feel immersed with the help of his imagination, if this is increased by a device that allows him to feel the virtual elements through touch, the sensation will be more real, pleasant and very tractive. [17, 18].

Therefore, if varied and entertaining virtual environments can be created to attract children's attention, they can be encouraged to acquire new knowledge and thus the teaching and learning process will be more effective. [20–25].

The present work presents the advances and results of the application of 3D environments realized in virtual reality helped by the use of a haptic device, in the teaching of basic concepts to children of initial education, such as: to recognize and to use colors, to recognize geometric figures, to locate objects in designated spaces, to recognize and to realize figures, finally to recognize and to write vowels. The haptic device will serve as a tool for interacting with the virtual environment, which may guide the child's hand to perform an action or stroke, or will also present a force in the child's hand to prevent the child from performing an incorrect action or drawing a stroke inappropriately, such as drawing the letter OR in the wrong direction. [26, 27].

2 Material and Method

The system has virtual environments realized with the software UNITY 3D, in addition it is possible to interact with the Geomagic Touch device, which indicates the position of the cursor and allows by means of the buttons to realize some actions like: select primary colors, combine colors, pick and place objects, also indicates when to start or finish the stroke, if the task is done correctly the haptic device does not present any force to the

action performed, otherwise prevents the child from continuing until you correct the error, at the end, an audio signal will tell the child if the task was successfully performed, always with words of encouragement even when the task has not been performed correctly. Both the inputs and outputs are managed with scripts made in Visual Studio with language C, these scripts execute functions that depend on the data received from the peripheral and the virtual environment that is used. With MatLab the data management algorithms are controlled, the validation of the traces made is carried out, based on the established pattern and the data entered with Geomagic Touch. Figure shows the block diagram of the implemented system (Fig. 1).

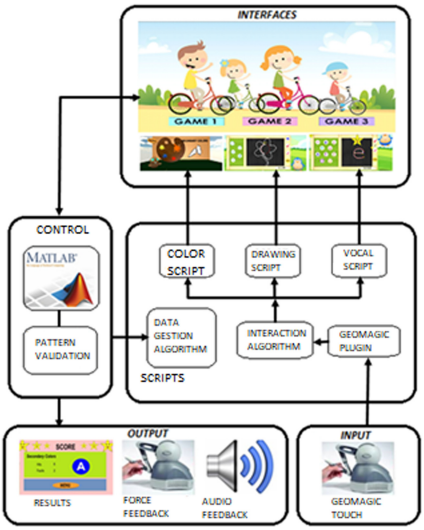

Fig. 1. Block diagram of Implemented system.

Input The device that allows giving the entries to the system is a Geomagic Touch, a haptic device that resembles the arm of a robot with six degrees of freedom and can be handled in a similar way to those of a mouse, also has the shape of a pencil, through this device the child can choose colors, draw strokes and write vowels.

Scripts

The scripts are a set of instructions programmed in language C# in Visual Studio, they are in charge of the administration of the system and specifically to deliver the outputs according to the inputs.

For the game that allows to select and locate objects, the child must choose the object with the help of the Geomagic Touch, when choosing the object he wants, thanks to the respective script the haptic device presents a feedback of forces that gives him the sensation of taking an object with a certain weight and when he moves it in places that are not allowed he has the sensation of colliding with the virtual objects that delimit this

space, which gives him a sensation of realism. For the stroke game, the device opposes incorrect strokes, just as for the vowel game, it opposes the child writing in the wrong direction. In addition, the scripts turn Geomagic Touch into a teaching device, since it can move autonomously guiding the child's hand to learn how to perform the task, before performing it by himself.

Interfaces
The interfaces are environments that present everyday objects in 3D to make it more realistic and more accepted by the child, is programmed using Unity 3D software, with which you can assign properties to the objects, such as rigidity, sound and animation among others. The properties of the objects give the child an experience that is both real and attractive, since it resembles a game in which the child can interact.

The environments try to adapt to the theories of Vigotsky, that is to say they try to create environments similar to the reality of the child but with a touch of play, since in this way the teaching-learning process is more effective.

Control
The Control of the System is performed by Matlab, interacts with Unity, receives information from the interfaces and the haptic device and based on these, provides the necessary information to Unity to indicate if the task was performed correctly or can manage the Geomagic Touch to perform a specific task such as guiding the child's hand to learn how to draw a figure or write a vowel.

To validate a stroke, Matlab takes the one made by the child and compares it with a pattern, using classifiers that use the Euclidean distance to determine if the stroke is very close to the pattern. To ensure that the haptic device terminal follows a path, a PID position control is used.

Outputs
Outputs are presented in different ways:

- Graphically in the environment, to indicate the progress of the task performed.
- With sound to give auditory indications and stimulate the child while performing the task or to indicate if it was done correctly or not.
- Finally, the Geomatic Touch can deliver a force feedback that opposes the action performed by the child if it is incorrect.

2.1 Use of the System

The system currently has six games:

Primary Colors - Allows you to recognize and learn primary colors, the child must choose the color that the system asks him to choose.

Spatial Notion - To improve his spatial perception, the child must choose a particular object and place it in a set position, the device generates a force of opposition to the child's hand through the terminal of the Geomagic Touch when the trajectory he tries to follow is incorrect or when he tries to place the object in a different place from the established one (Fig. 2).

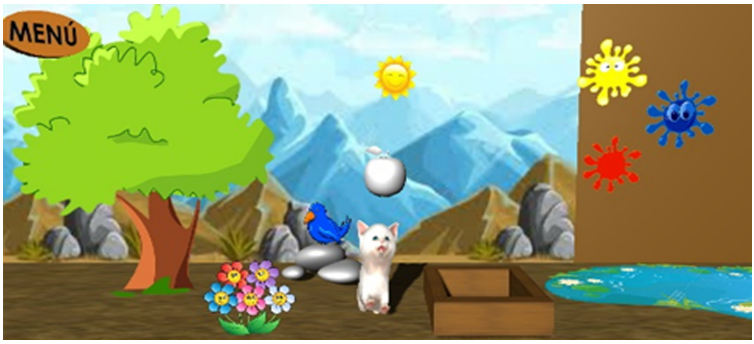

Fig. 2. Interface for learning primary colors and spatial notion.

Secondary Colors - In this case the child learns to combine two colors to form a secondary color, the system asks the child to choose the correct colors that combined serve to give color for example: a carrot or a bunch of grapes (Fig. 3).

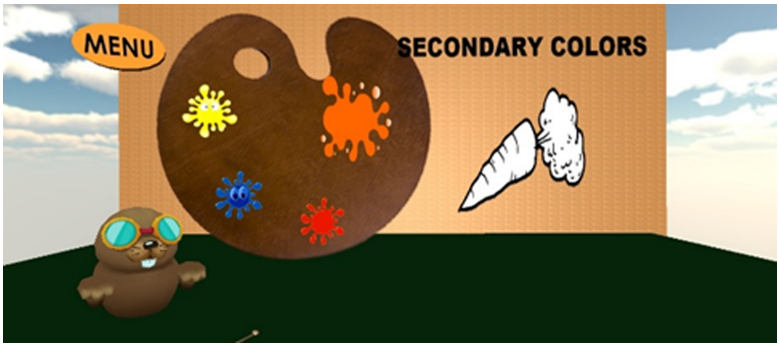

Fig. 3. Interface for learning secondary colors.

Geometric Figures - The child must recognize figures related to the environment, for example a rectangle with a door (Fig. 4).

Drawing of Figures - The aim is to improve the way the child draws a line, for this the system uses the Gemagic Touch as the hand of a teacher guiding the hand of the child, then behaves like a pencil for the child to draw the line by himself (Fig. 5).

Vowel Writing - Being a system for children in initial education, this game aims to give the notions necessary to write basic letters, in this case the vowels, in a similar way that in the previous case the system first behaves as a guide to teach the correct way to write each vowel and then allows the child to write it on its own, it is worth mentioning that in both cases if the child follows an incorrect trajectory the haptic device through force feedback will not allow him to continue until he corrects his error (Fig. 6).

Fig. 4. Interface for learning geometric figures.

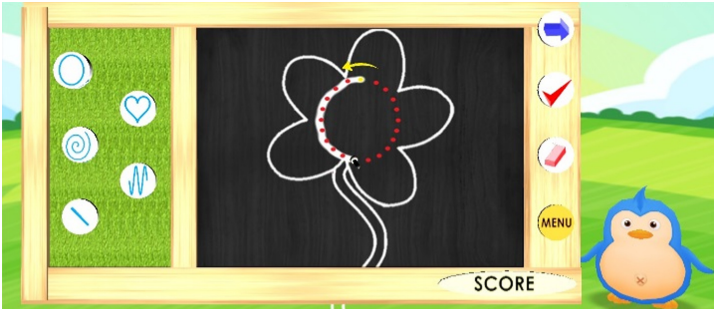

Fig. 5. Interface to develop the ability to draw strokes.

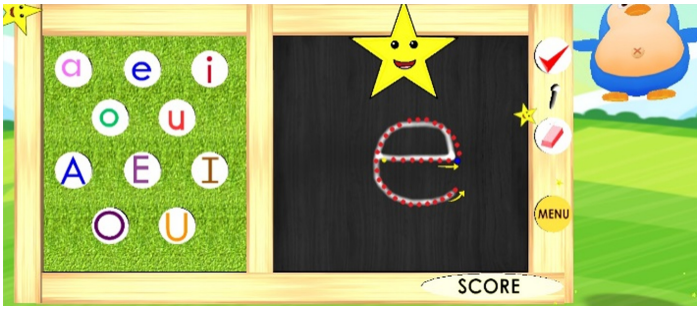

Fig. 6. Interface for learning how to write vowels.

3 Results and Discussions

3.1 Tests

The system was tested by 20 users (10 girls and 10 boys) between 6 and 9 years of age, users carried out the different activities proposed in the games under the supervision of the kindergarten teacher (Fig. 7).

Fig. 7. Children using the system.

Due to the age of the children the test is applied by means of observation and interview, during and after using the system, there is only one system due to the high cost, therefore the use is individual, nevertheless for better comfort and confidence in the children, the interview was carried out in groups of five children.

The following questions were used for the test:

Table 1. Questions to validate the implemented system.

Ord	Question	Value (1–10)
1	Are the graphics and elements used in the games pleasant?	
2	The selection of games is simple and easy to make?	
3	Are the instructions easy to follow?	
4	Are the games easy to make?	
5	Is the handling of the haptic device simple?	
6	Is the use of haptic device buttons simple?	
7	The results are easy to understand?	

Children should evaluate each question with values from 1 to 10 where 1 indicates low satisfaction and 10 indicates high satisfaction.

3.2 Results

When the child completes the tasks, the system shows the result obtained and also stores all the data so that the teacher can evaluate the performance of each child (Fig. 8).

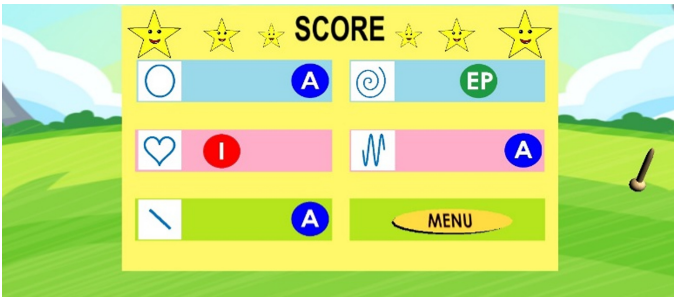

Fig. 8. Display where the results are shown.

The letters "A" indicate passed, "EP" is in the learning process but needs more practice and the letter "I" indicates that it requires more time and help to complete the task.

In general, the children had no problems performing the tasks using the system, the work was done in a versatile, cheerful and pleasant way.

By comparing the performance of the children with and without the use of the system, the following advantages were obtained:

- The children had more fun while they learned.
- Requested less help from the teacher.
- They showed greater interest because being virtual environments, children pay more attention.

The aspects mentioned above show that the system is designed properly, however to clear up doubts a test was performed on children, this test resembles a usability test with the necessary simplicity because it was applied in children. The questions applied are those shown in Table 1.

The results obtained are the following (Fig. 9).

As you can see in the results, there is a high degree of acceptance and satisfaction with the system.

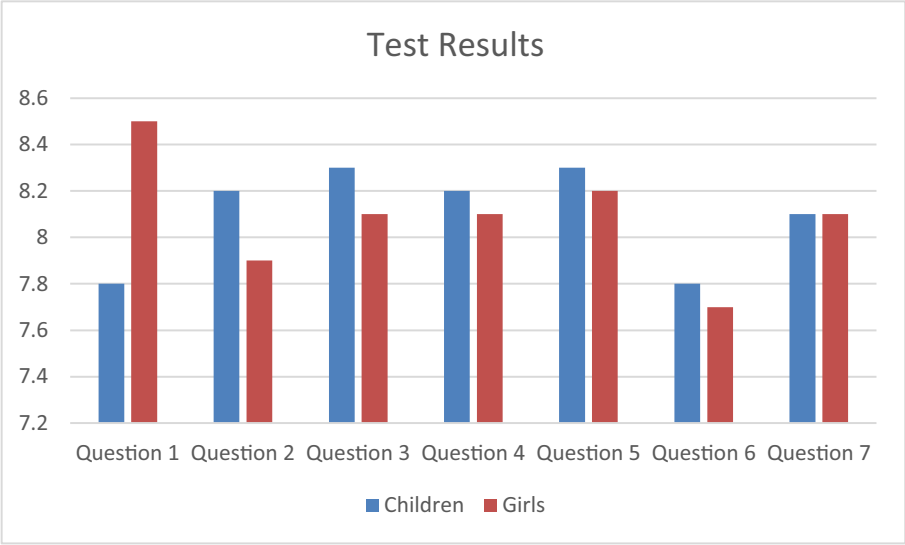

Fig. 9. Graph showing test results.

4 Conclusions

Education as the basis for the development of countries is extremely important, its improvement should always be sought and done as early as possible i.e. improvement in educational processes should begin in initial education.

Technology has the potential not only to improve an educational process but also to make it more attractive to all ages and much more so to children.

The proposed system is a very efficient alternative to improve the learning process in pre-school children, unfortunately due to its costs cannot be implemented in schools in the short term.

With the proposed system, the children learn in an entertaining way, the time they dedicate to learning is greater, on the other hand, the improvement in their abilities will be obtained in less time, in addition, the child acquires greater autonomy since although the supervision of the teacher is indispensable, the child requests less help.

References

1. Ankshear, C., Knobel, M.: New technologies in early childhood literacy research: a review of research. J. Early Child. Literacy **3**(1), 59–82 (2003)
2. Skaalvik, E., Skaalvik, S.: Teachers' perceptions of the school goal structure: Relations with teachers' goal orientations, work engagement, and job satisfaction. Int. J. Educ. Res. **62**, 199-209 (2013)
3. Blatchford, P., Kutnick, P., Baines, E.: Toward a social pedagogy of classroom group work. Int. J. Educ. Res. **39**(1–2), 153–172 (2003)
4. Méndez, R.: Investigación y planificación para el diseño de un aula de apoyo psicopedagógico y aporte de la misma al desarrollo y seguridad de la educación de niños con dificultades de aprendizaje (Tesis de Maestría). Instituto de Altos Estudios Nacionales Quito (2003)

5. Briones, M.: Guía metodológica correctiva integral neuropsicológica para dificultades específicas de lectura y escritura en niños/as de 3.er año de educación básica del Colegio Experimental El Sauce de Tumbaco" (Tesis de Pregrado), Universidad Politécnica Salesiana, Quito (2013)
6. Muñoz, X.: Representaciones y actitudes del profesorado frente a la integración de Niños/as con Necesidades Educativas Especiales al aula común. Revista Latinoamericana de Educación Inclusiva, pp. 25–35 (2008)
7. MinEduc, M.D.: Guía metodológica para la implementación del currículo de educación inicial. Ministerio de Educación del Ecuador, Quito, pp. 7–15 (2015)
8. Currículo de educación inicial 2014. Ministerio de Educación del Ecuador, Quito, pp. 12–16 (2014)
9. Satava, R.: Virtual reality: current uses in medical simulation and future opportunities & medical technologies that VR can exploit in education and training. In: Proceedings University of Washington Medical Center, USA, (2013)
10. Vahtivuori-Hänninen, S., Halinen, I., Niemi, H., Lavonen, J., Lipponen, L.: A New Finnish National Core Curriculum for Basic Education (2014) and Technology as an Integrated Tool for Learning. In: Niemi, H., Multisilta, J., Lipponen, L., Vivitsou, M. (eds.) Finnish Innovations and Technologies in Schools. SensePublishers, pp. 21–32 (2014)
11. Martínez, E.V., Villacorta, C.S.J.: Spanish policies on new technologies in education. In: Plomp, T., Anderson, R.E., Kontogiannopoulou-Polydorides, G. (eds) Cross National Policies and Practices on Computers in Education. Technology-Based Education Series, vol 1. (pp. 397–412) Springer, Dordrecht (1996) https://doi.org/https://doi.org/10.1007/978-0-585-32767-9_20
12. Wall, K., Higgins, S., Smith, H.: The visual helps me understand the complicated things': pupil views of teaching and learning with interactive whiteboards. Br. J. Educ. Technol. **36**, pp. 851–867 (2005)
13. Mar, N.Y.: Utilizing information and communication technologies to achieve lifelong education for all: a case study of Myanmar. Educ. Res. Policy Pract. **3**(2), 141–166 (2004) https://doi.org/10.1007/s10671-004-8241-y
14. Selwyn, N., Bullon, K.: Primary school children's use of ICT. Br. J. Educ. Technol. **31**(4), 321–332 (2000)
15. Peltenburg, M., Van Den Heuvel-Panhuizen, M., Doig, B.: Mathematical power of special-needs pupils: An ICT-based dynamic assessment format to reveal weak pupils learning potential. Br. J. Educ. Technol. **40**(2), 273–284 (2009)
16. Mangen, A., Walgermo, B., Bronnick, K.: Reading linear texts on paper versus computer screen: Effects on reading comprehension. Int. J. Educ. Res. **58**, 61–68 (2013)
17. Dinis, F.M., Guimarães, A.S., Carvalho, B.R., Martins, J.P.P.: Development of virtual reality game-based interfaces for civil engineering education. In: Global Engineering Education Conference (EDUCON), pp. 1195–1202. IEEE (2017)
18. Elliman, J., Loizou, M., Loizides, F.: Virtual reality simulation training for student nurse education. In: Games and Virtual Worlds for Serious Applications (VS-Games), 2016 8th International Conference on, pp. 1–2. IEEE (2016)
19. Zhang, K., Liu, S.J.: The application of virtual reality technology in physical education teaching and training. In: Service Operations and Logistics, and Informatics (SOLI), 2016 IEEE International Conference on, pp. 245–248. IEEE (2016)
20. Yu, X., Zhang, M., Xue, Y., Zhu, Z.: An exploration of developing multi-touch virtual learning tools for young children. In: Education Technology and Computer (ICETC), 2010 2nd International Conference on, vol. 3, pp. V3–4. IEEE (2010)
21. Chaney, C.: Language development, metalinguistic skills, and print awareness in 3-year-old children. Appl. Psycholinguistics **13**(4), 485514 (1992)

22. Clements, D., Swaminathan, S., Zeitler, M., l Sarama, J.: Young children's concepts of shape. J. Res. Math. Educ. **30**(2), pp. 192–212 (1999)
23. Achibet, M., Marchal, M., Girard, A., Kajimoto, H.: FlexiFingers: Multi-finger interaction in VR combining passive haptics and pseudo-haptics. In: IEEE Symposium on 3D User Interfaces (3DUI)/ Los Angeles, CA, USA, pp. 103–106 (2017)
24. Palluel-Germain, R., Bara, F., De Boisferon, A.H., Hennion, B., Gouagout, P., Gentaz, E.: A visuo-haptic device-telemaque-increases kindergarten children's handwriting acquisition. In: EuroHaptics Conference, 2007 and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems. World Haptics 2007. Second Joint, pp. 72–77. IEEE (2007)
25. Ahonen, T., O'Reilly, J.: Convergence of broadband internet, virtual reality and the intelligent home. Digital Korea, pp. 37–54 (2007)
26. Pilatásig, M., Tobar, E., Paredes, L., Silva, F., Acurio, A., Pruna, E., Sanchez, Z.: Teaching-learning system using virtual reality and haptic device to improve skills in children of initial education. In: Rocha, Á., Guarda, T. (eds.) MICRADS 2018. SIST, vol. 94, pp. 307–316. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-78605-6_26
27. Pilatásig, M., et al.: Virtual system for teaching-learning of initial education using a haptic device. In: De Paolis, L.T., Bourdot, P. (eds.) AVR 2018. LNCS, vol. 10850, pp. 118–132. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95270-3_8