

Educational Electronic Prototype to Support the Learning of Braille Prototipo electrónico educativo para apoyar el aprendizaje del braille

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Summary. The process of inclusion is dynamic and ongoing, requiring ongoing commitment from all members of society. For blind people to be educated and integrated into society, braille is crucial. Like sighted individuals, it enables them to access reading and writing, engage in formal education, find work, and appreciate literature and culture. For those who are blind or visually challenged, Braille is still an essential tool despite technological advancements. Designing a technological teaching tool that supports the teaching-learning process of the Braille language in the reading and writing modality for children with visual disabilities is the primary goal of this project.

Keywords: Disability, Braille teaching, Blindness

Resumen. El proceso de inclusión es dinámico y continuo, y requiere el compromiso constante de todos los miembros de la sociedad. Para que las personas ciegas se eduquen e integren en la sociedad, el braille es crucial. Al igual que para las personas videntes, les permite acceder a la lectura y la escritura, participar en la educación formal, encontrar trabajo y apreciar la literatura y la cultura. Para las personas ciegas o con discapacidad visual, el braille sigue siendo una herramienta esencial a pesar de los avances tecnológicos. El objetivo principal de este proyecto es diseñar una herramienta didáctica tecnológica que apoye el proceso de enseñanza-aprendizaje del lenguaje braille en la modalidad de lectura y escritura para niños con discapacidad visual.

Palabras Clave: Discapacidad, enseñanza de braille, ceguera.

1 Introduction

Disability, according to the World Health Organization (WHO), is a generic word that encompasses impairments, physical limitations of an activity, and constraints on participation. The activity's physical constraints make it difficult to complete a task, while participation limitations make it impossible to interact in crucial circumstances [1].

Additionally, according to the WHO, a visual handicap is a constraint in doing daily chores, which consequently impacts one's quality of life and opportunities for engagement with others [1].

1.1 Visual disability

The integration of individuals with visual impairments is a fundamental component of equitable opportunities and rights within society. Establishing an accessible environment and fostering inclusion are vital measures for achieving a more fair society that honors diversity.

Visual impairment is characterized by visual acuity and the extent of the visual field. Visual impairment is discussed when there is a substantial reduction in visual acuity despite the use of corrective lenses, or a marked decrease in the visual field. Visual acuity is the capacity of an individual to distinctly discern the form and contours of objects at a specific distance. The visual field denotes the area of space observable by an individual without the necessity of head or eye movement. An individual with typical vision possesses a horizontal visual field of 150° and a vertical visual field of 140°.

The World Health Organization categorizes visual function into four tiers: normal vision, moderate visual impairment, severe visual impairment, and blindness.

Moderate vision difficulty and severe visual impairment are categorized as low vision, whereas low vision combined with blindness constitutes the broader classification of visual impairment [2].

In Mexico, data from INEGI indicates that 7 million 650 thousand individuals reported having a disability, constituting 6.4% of the total population, with 1 million 561 thousand individuals experiencing visual impairment. Among individuals with visual impairments, 63.5% do not utilize any form of technological assistance, while merely 4.6% employ the Braille system [3].

1.2 Braille system

To carry out a communication between 2 or more people, there is a structure for this which is as follows: sender, as its name says, it issues the message, the next concept is the receiver, it is responsible for receiving the message from the sender, another element What is part of the structure is the message, it is defined as what you want to transmit to another person. Finally, in order for the objective of transmitting the message to be met, it is essential that there be a channel whose function is the physical medium. so that it can be transmitted.

One of the alternatives to communicate with a blind person is through the Braille language, this concept is not only and mainly a special reading and writing code. It is considered an alternative visual means of communication in conventional literacy through the sense of sight. Therefore, in the teaching and learning of this system, everything related to such mechanisms (its structure, impact on sensory and intellectual processes) [4].

Braille is defined as a system consisting of raised dots that allows blind people to read by touch, and for writing, it consists of a sheet, a strip, and a stylus. There is Braille signography for letters, numbers, punctuation marks and there is also an abbreviation system called Stenography [5].

The Braille system is of vital importance for people who are blind or visually impaired, as it provides them with access to written information and allows them to actively participate in society.

Braille is a tactile writing system designed specifically for people who are blind or visually impaired. It was invented by Louis Braille, a young blind Frenchman, in the 19th century. The Braille system is based on a series of tactile symbols or Braille characters that represent letters, numbers, punctuation marks and other symbols, allowing blind people to read and write independently.

Braille has been indispensable throughout history for people with visual impairments, as a necessary tool for communication, which goes beyond being a writing technique for the blind.

Thanks to this system of representation of alphabetic and numerical signs that uses dots as musical, mathematical, and scientific symbols, blind people can learn, educate themselves, and connect with their environment from an equitable and autonomous perspective.

1.3 Educational technologies and inclusion

ICTs are tools that promote equity, relevance, and inclusion in school learning environments and foster the development of skills such as reasoning, interpreting, arguing, proposing, modeling, decision-making, and problem-solving, among others. Therefore, their use as learning mediators, even for people with disabilities, is essential to achieving the goal of educational quality [6].

In [7] it is mentioned that electronic devices are commercially distributed that allow people with visual disabilities to read digital content translated into Braille, such as the BraiBook, which is a portable device that has an 8-point Braille cell based on the principle of piezoelectric materials and an audio system for greater ease in reading digital content, however, this is a personal device and does not allow interaction between teachers and students as a teaching tool in training environments, in addition there are no documented methodologies that use this type of devices for the training of people with visual disabilities.

Using ICTs can help overcome learning barriers related to disability, poverty, distance and geographical location [8] [9]. They can also help provide students, regardless of their needs, with the learning opportunities they need [10].

In [11] it is stated that ICT can help create a more inclusive learning environment by providing all students with access to educational information and resources.

It is essential to recognize the possibilities offered by ICT according to a series of authors [12] [13] [14] to generate processes that make quality learning possible for all students, they are diverse since they promote communication between all participants in the training action, break the barriers of space and time allowing integration and decontextualized and ubiquitous learning, offer the opportunity to access high quality materials from remote sites, promote flexible and ubiquitous learning, facilitate access to information, delocalize information and facilitate access to it regardless of the economic conditions of the place of residence, and present the information in the symbolic system most appropriate to the cognitive and physiological characteristics of the person.

The main objective of this work is to design an electronic prototype as a technological teaching tool that supports the teaching-learning process of Braille for reading and writing for children with visual impairments. The teaching tool promotes inclusion and inclusive education by providing an innovative way to teach and learn Braille.

The technological tool was developed in the laboratory of the Research and Development Group for Inclusive Technologies and Educational Innovation (GIDTIITEC, by its Spanish initials), at the Autonomous University of Baja California Sur (UABCS, for its Spanish initials).

2 Methodology

For the development of the project, a methodology based on Design Thinking and Agile Development was used [15]. This methodology balances user-centered design, rapid iteration, and continuous validation. To achieve the project's objectives, four stages were established, as shown in Figure 1.

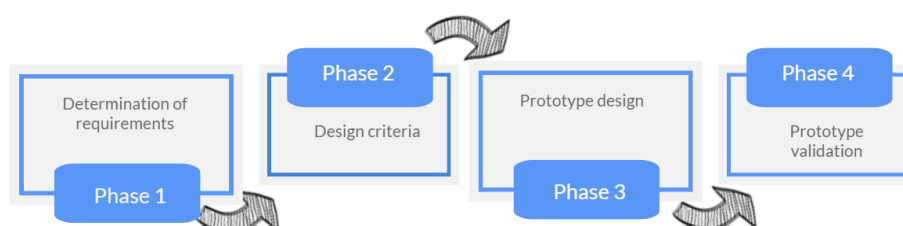


Figure 3. Project stages.

2.1 Determination of requirements

To determine the requirements for the electronic prototype, we worked in collaboration with experts in the area of special education, as well as with elementary education teachers. Based on the information gathered through questionnaires and interviews, the requirements for developing a system that provides a solution to the identified problem were established. During the working meetings, it was determined that for the prototype to function, it would be necessary to integrate hardware and software requirements, as shown in Figure 2.

Hardware requirements include a small device size and a touch interface for both writing and reading. Software requirements include communication with the hardware, the use of sounds, and teaching methodology.

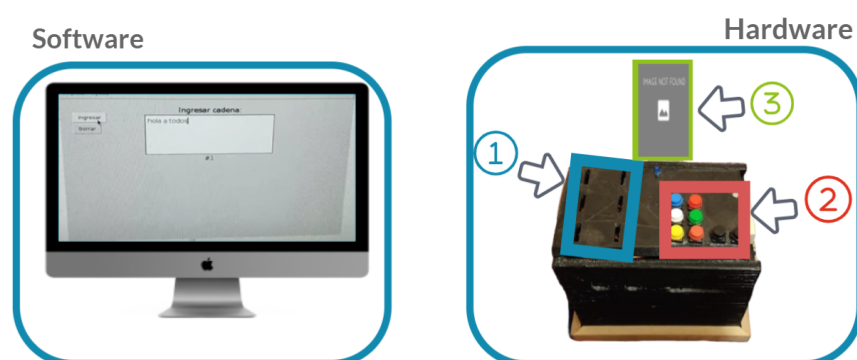


Fig. 2. Prototype hardware and software requirements.

2.2 Design criteria

Based on the analysis of the collected information and the hardware and software requirements, design criteria were established to be considered during the development of the electronic prototype as a learning tool. In the working meetings, strategies for learning the Braille system were analyzed, as well as the requirements and fundamental characteristics of the system's elements.

The reading and writing process in people with visual impairments is developed using the Braille system, which is adapted to the characteristics of the sense of touch (Álvarez, Sumba, & Arteaga, 2020).

There are various strategies to facilitate learning the Braille system, especially for children with visual impairments. These strategies seek to integrate the tactile, cognitive, and pedagogical aspects of the teaching-learning process to make learning Braille effective and engaging.

It is essential to consider a series of design criteria to ensure that the device is accessible, functional, educational, and suitable for children with visual impairments. The main design criteria to consider:

Touch and auditory interface: The design should focus on providing an accessible experience, where users can interact through touch and hearing (auditory feedback or spoken instructions).

Ergonomics: The device should be comfortable and easy for children to use, considering the size of their hands and ease of access to buttons or touch sensors.

Ease of use: The prototype should offer a simple and intuitive experience, especially for young users, avoiding complex interactions.

Adaptive design: The prototype should be suitable for different levels of Braille knowledge, allowing both beginners and more advanced users to use it effectively.

Clear and understandable interface language: Auditory instructions and any feedback provided should be clear and appropriate to the child's cognitive level.

Progress tracking: Implement functionality that allows the software to monitor and record the user's learning progress, offering suggestions or adaptations as the child improves.

Affordability: Components used in the design must be accessible and low-cost to ensure that the final product is affordable for mass production and can reach schools and families without prohibitive costs.

2.3 Prototype design

The prototype design was divided into two fundamental parts: hardware and software, which interact harmoniously. The hardware component of the prototype focuses on creating a physical platform that allows children to interact with the braille system through tactile exploration and haptic feedback. The software component of the prototype is responsible for processing input from the hardware, managing the interaction logic, and providing feedback to the user.

2.3.1 Hardware design

For the hardware design, it was necessary to use various electronic components that provide the device's functionality. The components required for operation are listed below, and the component connection diagram is shown in Figure 3.

1. Raspberry Pi programming board: this technology has its own operating system, which allows the user to program the GPIO ports, as well as design software to monitor the execution process.
2. Arduino programming board: This technology has an IDE for programming the board. Its task is to send signals so the servomotors can perform the corresponding actions.
3. Push button: it will be used to validate if the point was saved for the representation of the symbol in Braille.
4. LED: It will be used to verify the signal monitoring if the execution process is working correctly.
5. Servomotors: they will perform the operation for reading in Braille, for this, by means of the gears they will raise the needles that allow the user to have contact with them.
6. Resistors: used to control the flow of energy to protect various electronic components.
7. Buzzer: It is an alarm to notify the user if he or she is doing the exercises correctly for learning Braille.
8. Battery: to power the circuit.
9. Switch: so that the prototype can be turned on and off.

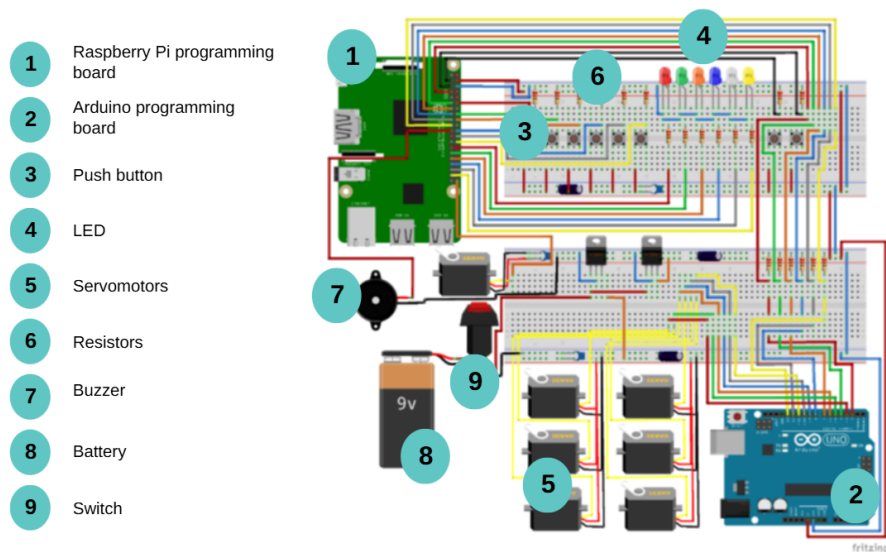


Figure 3. Connection diagram of hardware components.

2.3.2 Software design

Python was used for software development. Python was also used for programming the Raspberry Pi's GPIO ports, along with the RPi.GPIO library for configuring and controlling the GPIO pins.

Software plays a key role in managing interaction logic and providing appropriate feedback to users, as well as making the hardware work properly.

The software functionality is broken down into:

- Input processing. The software is responsible for receiving and processing signals sent by hardware input devices, such as buttons or touch sensors.
- Control of output components. After processing the inputs, the software controls the device's output, including auditory feedback by playing a sound or a spoken message through speakers, such as pronouncing the character or word the child is writing or reading in braille.
- Learning flow management. The software is responsible for guiding the user through the different stages of learning the Braille system. This includes real-time assessment while the child interacts with the device. The software can evaluate whether the answers are correct or incorrect, providing immediate feedback.

2.4 Prototype validation

During the validation phase, the prototype's functionality was tested. A validation and learning recognition instrument consisting of one session was applied, the objective of which was to evaluate Braille reading ability at a total of 10 levels.

3 Results

Tinkercad was used for the design, CAD modeling, and prototyping of the housing. The dimensions of the housing, which housed the final circuit, were 18 cm long by 15 cm high by 12.5 cm wide. Figure 4 shows the housing components, as well as the 3D printer used to make it.

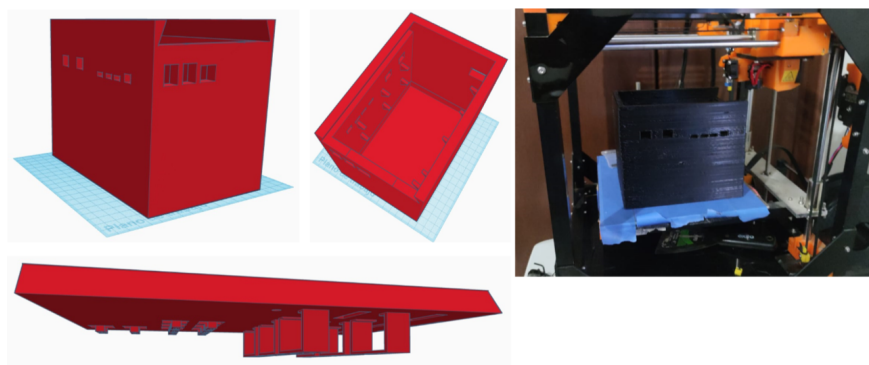


Figure 4. Design of the housing for the placement of the final circuit.

Tests were conducted to verify the prototype's proper functioning. The interaction between the Raspberry Pi and Arduino technologies and the software was verified. The synchronization of both elements was reviewed, with tests of the Braille reading and writing process involving a special education specialist and a visually impaired person, as shown in Figure 5.

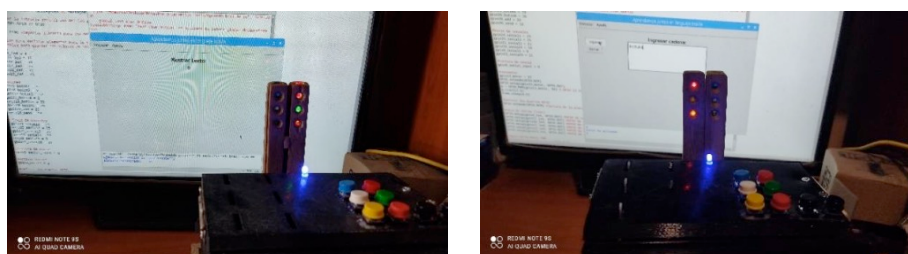


Figure 5. Tests of Braille reading and writing performance.

The tests carried out were: response time when writing, response time when reading, system validation when numbers were entered, and validation if it detects all lowercase letters of the alphabet. The graph in Figure 6 shows the response time for each of the tests performed, where a maximum response time of 5 seconds can be observed in the writing mode.

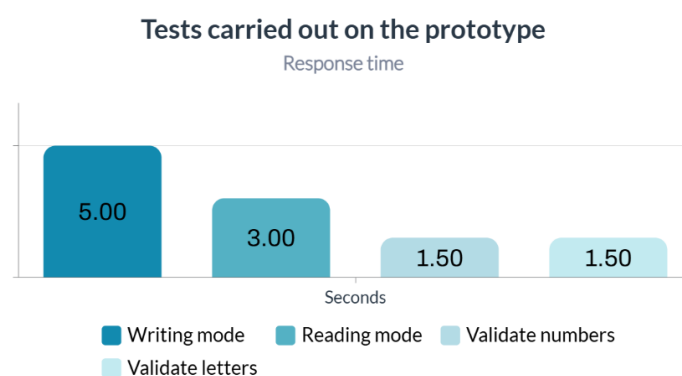


Figure 6. Prototype response time testing.

The graph in Figure 7 shows the percentages of correct answers for each of the tests performed.

Once the prototype tests were completed, an analysis was carried out to propose improvements, among which were identified: optimizing the algorithm and response time, reducing the size of the box and simplifying the circuit.

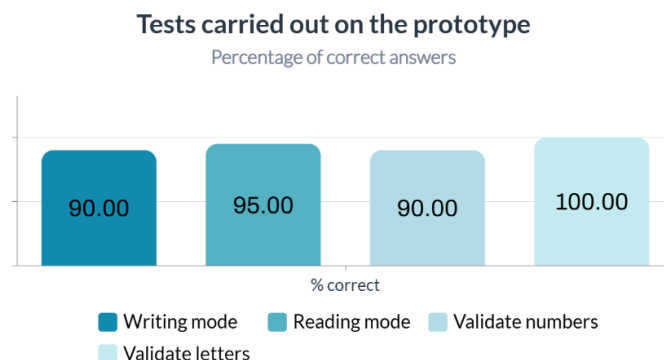


Figure 7. Testing for correct prototype responses.

4 Conclusions

The process of inclusion in students with disabilities is constituted as an emerging field that requires a global change in culture and a greater involvement of all the actors involved [17].

The development of the electronic prototype as a teaching tool represents a significant advance in supporting the teaching and learning process of Braille for children with visual impairments. Through the design and implementation of this technology, the feasibility of integrating accessible and interactive solutions that contribute to strengthening both Braille reading and writing skills from an early age has been demonstrated.

The results obtained throughout the design process show that the use of technological devices can promote student autonomy, motivate learning, and facilitate the work of teachers or tutors in the educational process. Furthermore, the didactic approach incorporated in the prototype allows for dynamic adaptation of content, providing a personalized experience tailored to the specific needs of users.

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