

Article

Design and Evaluation of a Multisensory Tangible Game Device for Inclusive Pre-Braille Literacy

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Abstract

This paper presents the design and evaluation of a multisensory tangible game device aimed at promoting pre-Braille literacy in children with varying visual abilities, including those who are blind, partially sighted, and sighted. The prototype integrates tactile, auditory, and visual elements to provide an inclusive and engaging learning experience. The device combines educational content with game-based learning, allowing users to interact with Braille characters through touch while receiving auditory feedback and visual cues. A focus group evaluation was conducted to assess the prototype's effectiveness, engagement, and educational value. Results indicated that the device successfully captured users' attention, with 83% recognizing its potential as a valuable educational tool for teaching pre-Braille literacy, 92% of participants reporting high engagement, and 75% of participants agreeing with the serious game approach. Feedback also highlighted areas for improvement, including the need for clearer tactile differentiation and more adaptive learning features. This study demonstrates the potential of combining multisensory feedback and serious gaming to enhance literacy education in children with visual impairments and provides insights into the further development of inclusive educational technologies.

Keywords: Braille; multisensory; inclusive; game; device; learning; literacy; serious game



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1. Introduction

Worldwide, approximately 2.2 billion individuals experience near or distance vision impairment. In at least 1 billion cases, vision impairment may have been averted or remains unaddressed (WHO, 2023). These limitations significantly impact navigation, safety, and the execution of daily tasks. According to studies, the WHO estimates that the number of people with visual impairment (presenting vision) is 285 million. Of these, 246 million have low vision and 39 million are estimated to be blind (WHO, 2025). Adaptive game design is a dynamic gamification approach that changes some elements of the game, such as game difficulty, feedback, challenges, and the leveraging of sensory and spatial predictability (Dong et al., 2022). In addition, adaptive learning is important because it allows instruction to be personalized to each student's needs and pace. This not only improves content

comprehension and retention but also optimizes learning time by focusing on the areas where students need the most support. It also fosters motivation and engagement by offering a more relevant and accessible educational experience (Wang et al., 2023).

The inclusion of people with visual impairments in educational environments continues to be a global challenge, especially for literacy acquisition processes that require tactile and cognitive adaptation (WHO, 2020). Braille, the tactile reading and writing system developed in the 19th century, remains an essential tool for blind individuals to access information and participate in society. However, traditional methods of teaching Braille often lack engagement, multisensory stimuli, and inclusive design that allows both visually impaired and sighted individuals to participate in a shared learning experience (Ardiansah & Okazaki, 2024; Gómez et al., 2017; Jaimes et al., 2021).

Recent advances in tangible user interfaces (TUIs), serious games, and universal design principles have opened new possibilities for creating learning environments that are both accessible and inclusive (Lang et al., 2023; Patil & Raghani, 2025). Multisensory devices, those that integrate tactile, visual, and auditory feedback, can significantly enhance the learning experience of users with varying levels of visual ability (Dong et al., 2022; Hahn et al., 2019). In this context, game-based learning emerges as a powerful strategy to increase motivation, reinforce memory, and promote social interaction across diverse user groups (Hersh & Leporini, 2018; Kazachiner et al., 2023; Othman et al., 2023).

The main research question is as follows: How can a tangible multisensory device integrating tactile, auditory, and visual stimuli enhance learning and interaction with pre-Braille concepts for blind children? The specific research questions are as follows: (1) How does the integration of tactile, auditory, and visual stimuli in a multisensory device improve the perception and retention of Braille patterns in blind children? (2) What are the perceptions and evaluations of teachers regarding the effectiveness of a multisensory device in teaching pre-Braille to children with and without vision?

Despite advancements in assistive technologies for the literacy of blind and visually impaired individuals, a gap persists in the design of devices that integrate multiple sensory modalities for pre-Braille instruction. Current approaches primarily focus on visual or auditory devices separately, which limits accessibility and participants' full interaction with educational content.

The objective of this study was to design and evaluate a tangible multisensory device that integrates tactile, auditory, and visual stimuli, promoting an inclusive approach to pre-Braille instruction for blind children. The purpose of this device is to facilitate learning and interaction with the fundamental concepts of Braille in an accessible and engaging manner. The specific objectives are as follows: (1) to design and implement a device that combines multisensory stimuli to enhance the perception and retention of Braille patterns and (2) to obtain feedback from teachers on the effectiveness of the device for teaching pre-Braille to children with and without visual impairments.

This paper presents the design and evaluation of a multisensory, tangible game device intended to support Braille literacy in an inclusive educational context. The proposed device allows blind, partially sighted, and sighted users to engage with Braille content through a game-based interface. It features six physical Braille dots, a command control, and colored tactile buttons with printed Braille labels. The system is connected to a computer from which a teacher assigns tasks and monitors progress. Unlike traditional Braille teaching tools, this prototype was conceptualized for use not only by blind learners but by anyone interested in learning Braille, thereby promoting awareness and empathy in sighted populations while enhancing learning for the visually impaired.

The prototype was evaluated by teachers with experience in Braille instruction and visual impairment education, whose feedback provided key insights into its usability,

pedagogical effectiveness, and inclusive design. This study contributes to the field of assistive technologies by demonstrating how tangible game-based tools can bridge the accessibility gap and foster shared learning environments for all.

2. Background

Globally, over 253 million people are visually impaired, with approximately 36 million people classified as blind and 217 million people experiencing moderate to severe visual impairment (WHO, 2025). For these individuals, Braille literacy is a fundamental skill that facilitates access to education, employment, and full participation in society. However, rates of Braille literacy remain alarmingly low, especially in developing countries, due to a combination of limited resources, a lack of trained instructors, and insufficient exposure to tactile learning tools (Munir et al., 2024).

2.1. Traditional Braille Teaching and Learning in Developing Countries

In developing countries, access to education for individuals with visual impairments remains a significant challenge, with Braille literacy being one of the most critical barriers to educational participation. According to the World Health Organization (WHO, 2025), approximately 90% of the world's visually impaired live in low- and middle-income countries, where access to education and specialized learning resources is limited. Braille, a tactile writing system developed by Louis Braille in the 19th century, is essential for blind individuals to gain literacy, access information, and participate in societal activities. However, the traditional Braille teaching methods prevalent in many developing countries often fail to meet the growing demand for education due to various factors, including resource constraints, a lack of trained teachers, and insufficient infrastructure.

2.1.1. Limited Access to Braille Teaching Resources

In many developing countries, the availability of Braille textbooks, Braille typewriters, and Braille line and learning resources remains severely limited. In many countries where public education systems are underfunded, the production of Braille resources is expensive and often inadequate. In Peru, according to research by Ávalos-Gómez and Ordaya-Díaz (2021), teachers identified the deficiencies of public schools in Peru because the school administration does not request the necessary materials from the Education Ministry, and only some schools have the slate and punch equipment needed to teach Braille. These materials are often in short supply for some schools.

Thus, on many occasions, the teachers make their own teaching materials to teach Braille Literacy using recycled materials; for example, Figure 1 shows the representation of the letter "a" with an egg carton and a disposable bottle cap, and Figure 2 shows the representation of the letter "b" with a carton and disposable bottle caps.

Other schools receive educational materials from the Ministry of Education, such as a slate and a punch device. The difficulty with this type of material is that it is too small for a first-time learner, and the other problem is that it is written one way and read another (the paper must be turned over). Figure 3 shows the ruler and pencil sharpener.

As a result, students with visual impairments often struggle with limited access to essential reading materials, which hinders their ability to develop literacy skills at the same pace as their sighted peers.



Figure 1. Carton and bottle cap.

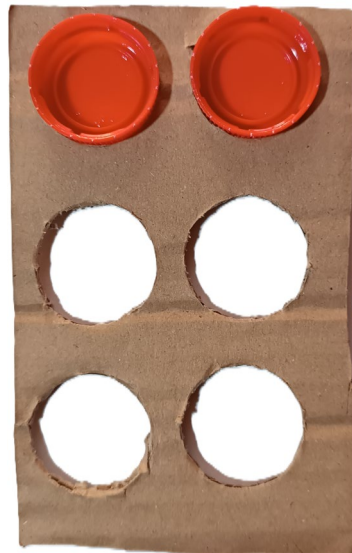


Figure 2. Carton from an egg box and bottle caps.

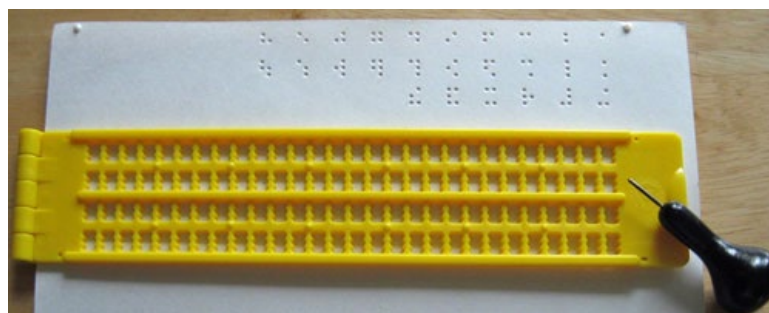


Figure 3. Slate and punch.

2.1.2. Teacher Training and Availability

Another challenge in Braille education in developing countries is the lack of adequately trained teachers. Effective Braille instruction requires specialized knowledge and teaching skills, which are often lacking in mainstream schools, particularly in rural areas. Teacher training programs in many developing countries are insufficient, with limited opportunities

for teachers to acquire the necessary skills to teach Braille effectively (Hoskin et al., 2024). Moreover, many teachers of the blind have not received adequate training in modern assistive technologies or inclusive teaching methodologies, further compounding the difficulty of integrating Braille instruction into broader educational systems.

2.1.3. Traditional Instructional Methods

Traditional Braille instruction often relies on manual, repetitive methods of teaching that focus heavily on memorization. In such approaches, students typically learn Braille through physical writing exercises, often using Braille slates and punch equipment, which can be slow and cumbersome. These methods, while essential in the absence of technological solutions, do not engage students in dynamic or interactive learning experiences. Research has shown that the lack of engagement and interactive elements in traditional Braille education can lead to high dropout rates and a sense of frustration among students, which ultimately hampers their academic progress (Al-Smadi, 2015).

Furthermore, traditional Braille teaching methods do not always consider the diverse needs of learners with visual impairments. For example, some students may also have additional disabilities that require specialized teaching approaches, such as those with cognitive disabilities or multiple disabilities. In these cases, the traditional methods of teaching Braille may not be flexible enough to cater to their unique learning needs, and the lack of inclusive, multimodal teaching tools exacerbates this issue.

2.1.4. Barriers to Inclusive Education

In many developing countries, inclusive education policies are still in their infancy, and children with disabilities, including those who are blind or visually impaired, are often excluded from mainstream education systems. Instead, students with visual impairments may be placed in segregated schools or programs, limiting their opportunities for social interaction with sighted peers and reducing their access to a comprehensive education. The United Nations Convention on the Rights of Persons with Disabilities (CRPD) advocates for inclusive education as a fundamental human right (ONU, 2016). However, in developing countries, implementation remains challenging due to insufficient policy support, limited funding, and cultural attitudes that often marginalize individuals with disabilities.

In this context, traditional Braille teaching methods continue to prevail, despite their limited scope and effectiveness in fostering long-term literacy and learning for visually impaired individuals. To address these issues, there is a growing need for innovative solutions that can enhance Braille instruction through modern technologies, more interactive pedagogies, and inclusive education practices that consider the needs of all learners, regardless of their visual or cognitive abilities.

Traditional Braille instruction is often manual, repetitive, and unidimensional, relying heavily on embossed paper and memorization methods. While effective for some learners, this approach frequently lacks engagement and fails to leverage the potential of modern educational technology (Nadeem et al., 2023). In recent years, assistive technology and game-based learning have been explored as promising alternatives to support Braille instruction. Serious games and tangible user interfaces (TUIs) can offer learners immediate feedback, sensory stimulation, and increased motivation, which are critical factors for maintaining attention and supporting cognitive retention in students with disabilities (Reisinho et al., 2021; Sanchez-Morales et al., 2020).

2.1.5. Our Approach: All Means All

Despite these advances, most Braille learning tools are designed exclusively for blind users, excluding individuals with partial sight and limiting collaboration in inclusive educational environments. This design limitation reinforces separation rather than integration,

missing an opportunity to foster inclusive learning spaces where both sighted and visually impaired individuals can interact with the same content in meaningful ways (UNESCO, 2021). Universal Design for Learning (UDL) principles emphasize the importance of creating tools that are adaptable to a wide range of users, regardless of sensory or cognitive differences. Educational technologies grounded in these principles can bridge accessibility gaps and encourage empathy, awareness, and shared learning experiences, so that Braille learning tools can be designed for all kinds of learners, including individuals with different abilities (Antoninis et al., 2020; UNESCO, 2021).

Our approach is designed to be inclusive and accessible to individuals across the spectrum of visual abilities, including blind users, those with partial sight, and individuals with normal vision. This inclusivity is central to the design and functionality of the prototype, which integrates multiple sensory modalities—touch, sight, and sound—to accommodate different learning needs.

2.1.6. Our Approach: Multisensory Stimuli

The multisensory approach to education, which integrates multiple sensory modalities (Fuccio & Mastroberti, 2018), such as tactile, auditory, and visual stimuli, has been recognized for its ability to enhance learning outcomes, particularly for individuals with sensory impairments. By engaging various senses simultaneously, this approach not only aids in information retention but also promotes a more interactive and immersive learning environment. For Braille literacy, the multisensory approach allows for the integration of tactile reading with auditory feedback, reinforcing the learning process and making it more enjoyable and effective for learners of different abilities. Figure 4 shows the multisensory approach.

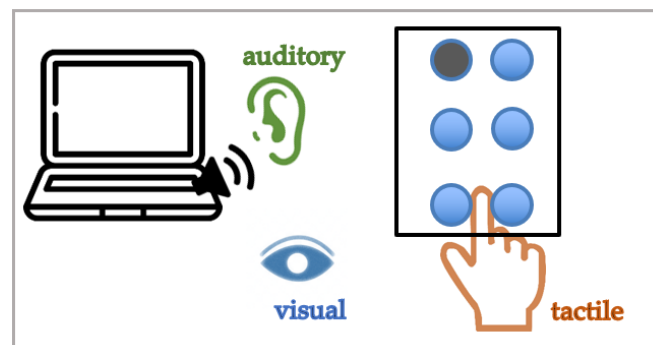


Figure 4. Multisensory stimuli approach.

The design of a tangible game device incorporating multisensory feedback has the potential to transform the way Braille literacy is taught, making it more inclusive, accessible, and motivating for a wider range of users, from children to adults with varying levels of Braille proficiency. The device's ability to combine tactile interaction with auditory cues allows learners to connect physical and auditory feedback to the Braille characters they are learning, fostering a deeper, more intuitive understanding of the Braille system.

2.1.7. Educational Game

Furthermore, research highlights the pedagogical benefits of multisensory approaches for learners with visual disabilities. Combining tactile, auditory, and—when applicable—visual feedback has been shown to improve concept retention, engagement, and learner autonomy (Panceri et al., 2024). Incorporating multisensory design into Braille learning tools not only benefits blind learners but also offers an entry point for sighted individuals

to engage with the Braille system, expanding the potential impact of such tools across different communities (Bitzas et al., 2019).

In response to these challenges and opportunities, the present study introduces and evaluates a multisensory, game-based device designed to teach Braille in an inclusive manner. This tool allows blind, low-vision, and fully sighted individuals to engage with the Braille content through tactile and visual interaction, promoting universal access to literacy.

3. Related Work

The intersection of assistive technology, Braille literacy, and inclusive education has generated significant interest in recent decades. Researchers and practitioners alike have explored various strategies to improve Braille acquisition, ranging from digital refreshable Braille displays to serious games and tangible learning environments. However, challenges remain in creating tools that are not only pedagogically effective but also inclusive, engaging, and scalable.

Several efforts have focused on creating low-cost Braille education devices. For instance, the BrailleBuddy proposed by Lang et al. (2023) describes that learning to read Braille is essential for the academic performance of individuals with blindness or significant visual impairment. They examine methods to enhance early Braille learning using tangible computing. Through a human-centered, inclusive design process involving interviews, six design iterations with prototypes, and feedback from experts, students, and instructors, they developed BrailleBuddy, a tactile user interface that aids children with visual impairments in learning Braille. They assessed BrailleBuddy in user research with youngsters with visual impairments. The findings indicate that BrailleBuddy fosters intrinsic motivation for Braille acquisition and can be utilized by youngsters independently. BrailleBuddy enhances the educational program by enabling youngsters to engage with and investigate Braille characters at their own pace, thereby reducing the difficulty of acquiring Braille literacy.

Similarly, Moctezuma (2023) developed a project that involves the building of a prototype aimed at developing an experimental educational resource for children with visual impairments, in accordance with its development and research phases. The function and its constituent pieces are delineated using the pre-book format while simultaneously establishing a connection with the alphabet and the Braille system from an early standpoint. The objective is for children to acquire knowledge of colors through sensory experiences, tactile perception, interpretation, and Braille reading to comprehend their surroundings. Conversely, the resource aims for integration into the educational process, enabling sighted individuals to assist in children's learning by offering a resource that incorporates both tactile and visual reading systems.

Likewise, Sandoval-Bringas et al. (2023) describe that several subfields of science and technology have shown an interest in raising awareness about the importance of aiding people who have disabilities. Visual perception accounts for a significant portion of the total information that is accessible to individuals. People who are visually impaired are severely impacted as a result of this, and they need to look for ways and alternatives that will enable them to obtain this information. The current situation is that technology has made it possible to introduce new kinds of education and communication with those who have disabilities. Furthermore, there is a growing interest in the incorporation of these technologies into instructional strategies. A mobile application that integrates gamification features that can be used by youngsters to learn Braille signs is the primary purpose of this study. The program will be designed this way. Within the realm of education, gamification is a significant trend that is utilized as a means of motivating pupils to engage in activities or projects that they would not normally engage in. Positive conclusions can be drawn from the preliminary findings that were collected.

Similarly, [Hilditch \(2024\)](#) describes the significance and benefits of using pre-Braille activities in a kindergarten classroom, irrespective of students' visual abilities. They enquire about the necessary resources and support needed for implementing more inclusive lessons in the classroom, as well as how to raise awareness of the Braille writing system. Semi-structured interviews and co-creation sessions were employed to collect data, alongside the conventional literature review. Thirteen individuals engaged in the sessions. By engaging with a community of experts, educators, and parents, areas for support and the needs of users were identified and integrated into the design process and the exploration of design options. The intended product promotes inclusive education, collaboration, and communication among students of varying abilities. The data indicates a robust link between pre-Braille activities and kindergarten classroom instruction. Pre-Braille activities aim to enhance bilateral coordination, tactile sensitivity, light touch, dexterity, and mobility, all of which are essential for reading Braille, which is a tactile writing system. The purpose of this device is to use several tactile engagement methods in the kindergarten classroom that enhance interest in pre-Braille and the Braille writing system. This is particularly crucial for individuals who subsequently require the acquisition of the official Braille code. The intended product, a pouch that promotes various forms of tactile interaction and an activity prompt system, serves as a source of inspiration, enabling students and teachers to collaboratively develop classroom activities.

Likewise, [Avendaño Mejía and Villa Cajilima \(2019\)](#) describe the purpose of this article as providing particulars regarding the design and implementation of an interactive device for the purpose of learning pre-Braille. For the purpose of forming letters and numbers, the user has access to extra pieces that represent the points in relief of the Braille system. These extra pieces can be reproduced phonologically using buttons with varying textures and distinct phrases for each individual symbol. The device was developed using open-source software and hardware development, specifically the Raspberry Pi and the Python programming language, respectively. The completed device possesses a hundred percent effectiveness in recognizing the symbols of the Braille system and reproducing them in a phonological manner. Furthermore, it was validated by a specialist team in the field of education.

4. Materials and Methods

4.1. Design Approach

This study adopted a user-centered and inclusive design methodology, aimed at developing and evaluating a multisensory and game-based device for Braille literacy that accommodates users with full vision, partial vision, and blindness. The research process followed three stages: (1) conceptualization and prototyping of the device; (2) iterative usability refinement; and (3) qualitative evaluation conducted with experienced educators in the field of visual disability and Braille instruction.

4.2. Participants

The evaluation involved a total of 12 educators (N = 12) with professional expertise in teaching Braille to students with blindness or low vision. Of these, eight teachers were affiliated with the Ilumina, Blindness and Low Vision Center in Mexico City, Mexico, and four teachers were from Peru. All participants had a minimum of five years of experience in the field of special education, with a focus on Braille instruction and the use of assistive technologies. Their feedback was critical for assessing the pedagogical value, usability, and inclusivity of the developed prototype. [Figure 5](#) shows the teachers involved in this research work.



Figure 5. The teachers of the Ilumina, Blindness and Low Vision Center.

4.3. Pre-Braille Device Design Description

The design of the prototype is a tangible Braille interface with six raised dots replicating the standard Braille cell layout. It features a command control panel equipped with color-coded buttons labeled in Braille and printed text to support both fully blind and partially sighted users. The device connects via USB to a computer interface, from which an instructor can assign Braille exercises, monitor responses, and adapt tasks in real time.

4.3.1. Game-Based Sensorial Activities

The activities in this educational game were designed to promote pre-Braille literacy in an interactive and motivating way. To develop a sense of touch, 6 Braille dots are used, allowing students to touch the different Braille alphabet symbols with the tips of their fingers, fostering tactile comprehension. On the other hand, for the development of the auditory sense, the computer's speakers emit sounds representing each vowel or letter of the Braille alphabet, which helps the student reinforce the development of their auditory sense. Finally, Braille code recognition involves each Braille dot having a specific encoding (1), (2), (3), (4), (5), and (6), as shown in Figure 6. Therefore, as they play, students must associate these positions with the formation of the vowel or letter.

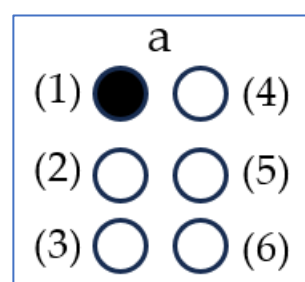


Figure 6. Braille codification.

4.3.2. Game-Based Software Interface

The game begins when the teacher assigns an exercise to the student, which can be vowels, letters, alphabet, or custom. Then the teacher can select the options for the type of exercise, which can be sequential or random, as well as the level of randomness; they enter the student's name and click to start the game. Let us suppose that the vowel exercise is selected (a, e, i, o, u) sequentially and with very low randomness (depending on the player's level, this can be varied and made more complex); then, for each of the vowels, the computer speaker emits its respective sound, and on the 6-dot Braille device, the Braille

dots are raised. Then the device has a game controller that has the options of correct, incorrect, previous, next, and repeat the sound. Figure 7 shows the software interface.

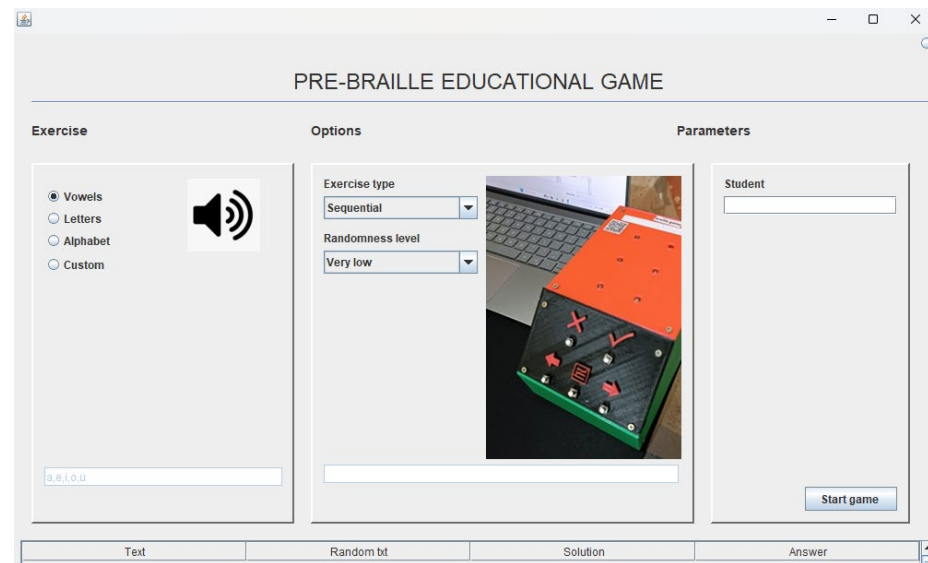


Figure 7. Braille software interface.

4.4. System Architecture

The system architecture is designed to support a multisensory educational experience, integrating tactile, auditory, and visual elements to enhance learning for users with varying degrees of visual ability.

- (A) The teacher uses computer software and assigns an exercise to the student to help them learn the Braille alphabet. For example, the teacher types the letter “a.”
- (B) The computer, using software, transforms the letter typed by the teacher into an auditory representation, for example, the sound of the letter “a.”
- (C) The transformed letter is played through the speaker, allowing the student to hear that sound, for example, the sound of the letter “a.”
- (D) Using a USB cable (type A male and type B male), the computer and the pre-Braille device are connected. This allows for power supply and bidirectional data transmission.
- (E) The pre-Braille device consists of a cell with six Braille dots. Each Braille dot is driven by a servomotor and an LED (Light Emitting Diode). The purpose of the servomotor, connected to the LED, is to raise or lower a Braille dot. If the teacher taps the computer and the speaker makes the sound of the letter “a,” then the pre-Braille device must also graphically represent the Braille dots for the letter “a,” meaning the first dot in the upper left corner must be raised, and all the other dots must be lower.
- (F) The device has command control so that the student can play the game. F1 indicates that the letter emitted by the speaker and the letter formed on the pre-Braille device are the same; therefore, it is correct. F2 indicates that they do not match; F3 goes back to the previous exercise; F4 proceeds to the next exercise; and F5 repeats the letter sound through the computer speaker.
- (G) Using this pre-Braille game, the students develop their auditory, visual, and tactile senses. Figure 8 shows the system’s architecture.

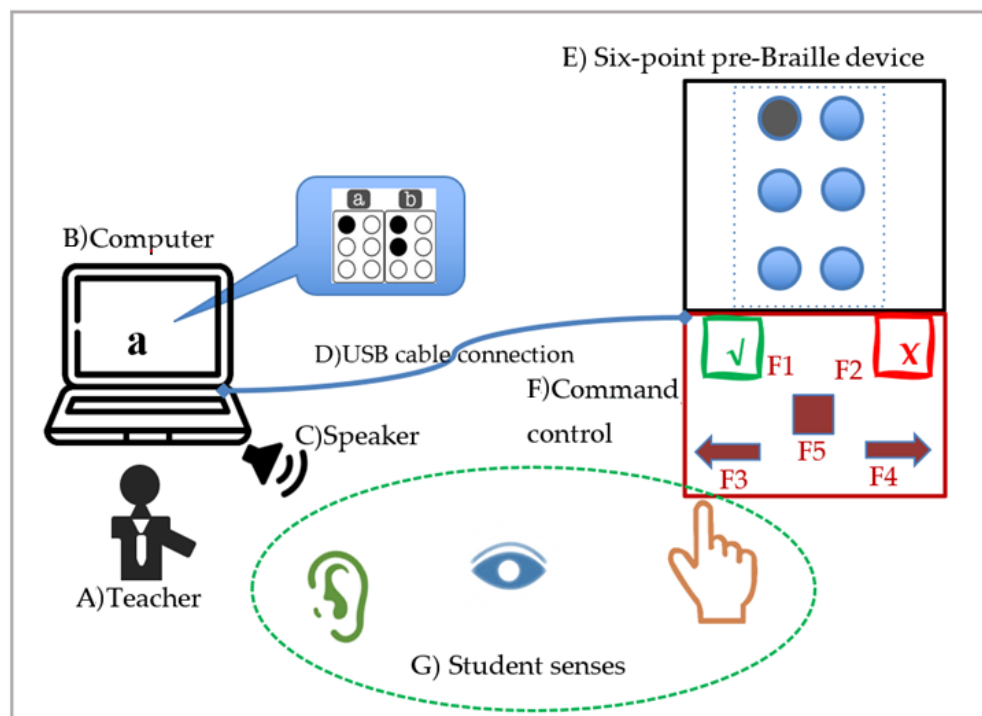


Figure 8. The system's architecture.

4.5. Pre-Braille Prototype

The pre-Braille prototype consists of three main components: the computer with a speaker, the Braille system with six points, and command control; in addition, there is a QR link for students with normal vision to learn more about Braille literacy. Figure 9 shows the pre-Braille prototype.

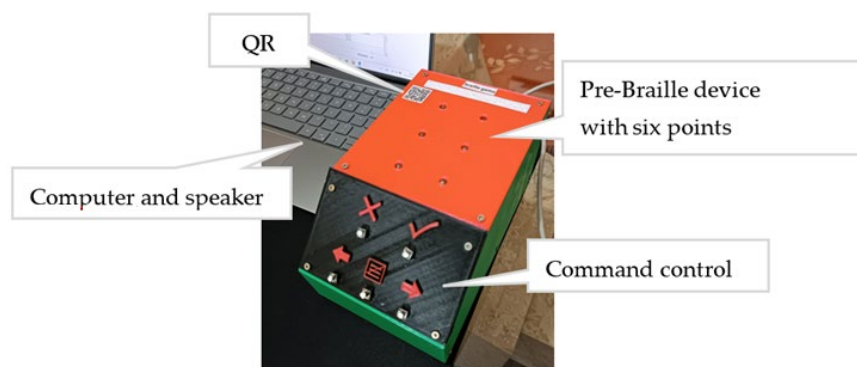


Figure 9. Pre-Braille system prototype.

4.6. Evaluation Procedure

The evaluation process was carried out over two periods and with two different groups; the first test took place in Mexico on 3 March 2024, and the second test took place in Peru on 21 September 2024. In Mexico, 8 participants were included, and in Peru, 4 participants were included. The expert group of teachers included those who were completely blind, had low vision, and had normal vision. Each participant was engaged in a group evaluation session lasting approximately 60 to 90 min, structured into three phases: (a) Introduction and Demonstration: The researchers explained the purpose, operation, and educational goals of the device; (b) Interactive Testing: Participants tested the device in a simulated teaching context, completing a set of Braille exercises designed for beginner

learners; (c) Feedback and Reflection: Participants completed a focus group semi-structured interview to provide qualitative feedback. Figure 10 shows the prototype.



Figure 10. Testing the Pre-Braille system.

4.7. Data Collection Instruments

The technique used for the evaluation of the system was a focus group, and the instrument for data collection was a semi-structured focus group guideline, focused on evaluating the pedagogical utility, accessibility for different user types, and its practical integration into teaching routines. In addition, we used a researcher's field note, and important observations were found during the user interaction, including behavior, response time, and spontaneous comments.

4.8. Data Analysis

In this research paper, qualitative data from interviews and observational notes were processed using thematic analysis, coding the collected data by categorizing the feedback into various themes or patterns. These themes included areas like "user engagement", "device usability", "tactile feedback effectiveness", "auditory support", "visual inclusivity", and "learning outcomes".

First, the transcripts from the focus group discussions were reviewed and inductively coded by a single researcher, who identified emerging patterns from the participants' feedback. Subsequently, to ensure the validity and reliability of the analysis, a second researcher reviewed the initial categories and themes. Discrepancies between the two researchers were resolved through discussion and consensus, ensuring consistent coding and high inter-coder reliability. This multiple review process was crucial to ensure that the themes accurately reflected the participants' perceptions.

5. Results

The results of the evaluation of the multisensory tangible game device for inclusive pre-Braille literacy were based on feedback collected from a focus group consisting of blind, partially sighted, and sighted teachers. The evaluation focused on user engagement, the educational value of the prototype, its effectiveness as a teaching tool, and the appeal of the serious game component. Responses were gained to the following four key questions: "Do you like this prototype?", "Do you think it can be useful for teaching?", "Did the prototype engage you?", and "Do you like this serious game?". The teachers provided valuable insights into the strengths and areas for improvement of the device.

5.1. Overall Impressions of the Prototype

When asked whether participants liked the prototype, the majority of participants provided positive feedback. Many described the device as “fun” and “interactive,” particularly appreciating the combination of tactile, auditory, and visual features. Several participants, especially those with partial sight, noted that the clear contrast in the visual components made the device easy to use. However, some users indicated that the tactile elements could be further enhanced for clearer differentiation between Braille symbols, particularly for children with no prior experience with Braille. Overall, 83% of participants expressed a favorable response, with a few suggesting minor adjustments to improve the usability of the tactile components.

5.2. Perceived Educational Value

Regarding the question of whether the prototype could be useful for teaching, the responses were generally positive. The majority of participants (83%) agreed that the device would be beneficial for teaching pre-Braille literacy, especially in terms of introducing tactile recognition and associating sounds with Braille characters. Teachers in the focus group highlighted the device’s potential to create an engaging learning environment where children could learn through touch and sound. However, a few participants suggested that additional educational content, such as more interactive activities or lessons, could further enhance its value in the classroom setting.

5.3. User Engagement

In terms of engagement, the results showed a strong positive response, with 92% of participants stating that the prototype kept their attention and was enjoyable to use. The game-like structure of the prototype was particularly praised for making learning enjoyable. Children were able to engage with the device for extended periods, with many expressing a desire to continue exploring it. One child mentioned, “I didn’t want to stop playing because I wanted to know what would come next.” Nevertheless, a few users noted that the device could benefit from more diverse challenges or levels to keep users engaged for longer periods, especially as they progress in their learning.

5.4. Serious Game Appeal

When asked if they liked the serious game aspect of the prototype, there was a mixed but generally positive response. The majority of participants (75%) indicated that they enjoyed learning through play, citing that the combination of learning and gaming made the experience fun and less intimidating. Sighted teachers particularly appreciated the game’s competitive and exploratory aspects, which allowed them to work together with visually impaired peers. On the other hand, a small group (approximately 25%) expressed indifference or preference for a more traditional learning approach, indicating that some children may not fully resonate with the game-based learning method. This suggests that while the game approach works for many, future iterations might consider incorporating a more flexible learning environment to cater to different preferences.

6. Limitations

Despite the positive results obtained, this study has some limitations that should be considered. The evaluation was conducted only with teachers who have experience teaching Braille to children with and without visual impairments, and no evaluation was conducted with the students themselves.

On the other hand, the lack of complete control over external variables, such as the teachers' prior experience level or variability in the quality of instruction provided by the teachers, might have influenced the results obtained.

7. Discussion

The results of this study represent a preliminary evaluation and highlight the potential of a multisensory tangible game device for enhancing pre-Braille literacy education in children with varying degrees of visual impairment. Overall, the findings indicate that the prototype successfully engages users and provides educational value through a combination of tactile, auditory, and visual elements. However, several key insights from the focus group's feedback suggest areas for refinement and further development to ensure broader applicability and effectiveness.

7.1. Educational Value

According to the opinion of the teachers and the focus group's feedback, it was confirmed that the prototype could hold significant potential as a tool for teaching pre-Braille literacy; 83% ($10/12 \times 100$) of participants saw the device as a useful educational resource, particularly for introducing tactile recognition and associating sounds with Braille characters. This aligns with [Jaimes et al.'s \(2021\)](#) research, where a BrailleBud was developed; this is a low-cost teaching tool that encourages pre-kindergarten and first-grade children to learn the Braille alphabet. Both articles have an educational value for children.

Future development of the prototype could include more comprehensive lessons or tasks that cover a broader range of learning objectives related to Braille literacy, such as spelling or word formation. Expanding the educational content could help solidify the device's role as a comprehensive educational tool.

7.2. Engagement

According to the opinion of the teachers and the focus group's feedback, the user engagement was positive, with 92% ($11/12 \times 100$) of participants indicating that they found the prototype engaging and enjoyable. This approach aligns with similar studies that emphasize the need to make digital game-based learning for students to encourage engagement and motivation. This is a promising result, as engagement is a critical factor in educational success, particularly for children with disabilities.

Additionally, some teachers expressed a desire for more challenges or levels, which suggests that as users become more familiar with the device, they may require increased difficulty or variety to maintain their engagement. This feedback aligns with similar studies that emphasize engagement and the need for progressive difficulty in serious games ([Menestrina et al., 2021](#); [Song et al., 2023](#)). Thus, future iterations of the prototype could incorporate more adaptive levels or challenges that evolve as users' skills improve, ensuring that the device remains stimulating and effective for learners at different stages.

7.3. Serious Game Component

Based on the teachers' opinions and feedback from the focus group, the serious game approach of the device, which combines learning with play, was particularly well received. The game-like elements seemed to effectively motivate children, encouraging them to engage with the device for extended periods, which is essential for maintaining their interest and facilitating learning. The serious game approach was generally well-received, with 75% ($9/12 \times 100$) of participants enjoying the game-like aspects of the device. Learning through play is widely regarded as an effective method of teaching, especially for children ([Garcia et al., 2025](#); [Hatzigiannakoglou & Kampouraki, 2016](#); [Hersh & Leporini, 2018](#)). The fact that the serious game engaged both sighted and visually impaired children suggests

that the prototype has the potential to promote inclusive learning environments, where sighted children can work collaboratively with those who have visual impairments. This aspect of the prototype aligns with the goal of fostering inclusivity through interactive learning tools.

However, a small portion of the participants expressed a preference for more traditional learning methods, which suggests that the serious game component may not resonate with all users. This raises the following question: are some teachers unfamiliar with the use of ICT? Hence, it is important to train teachers who teach students with special needs in the use of ICT.

8. Conclusions and Future Work

8.1. Conclusions

This study on the “Design and Evaluation of a Multisensory Tangible Game Device for Inclusive Pre-Braille Literacy” is a preliminary evaluation that demonstrates the significant potential of combining tactile, auditory, and visual elements to enhance the learning experience of children with varying degrees of visual impairment. The research aimed to create an inclusive educational tool that bridges the gap between different learning needs, supporting early literacy development for blind, partially sighted, and sighted children alike.

Feedback from the focus group indicated that the device holds substantial educational value, with 83% of participants recognizing its potential as a tool for teaching pre-Braille literacy. The tactile elements, particularly the Braille characters, were beneficial in promoting early recognition of symbols, while the auditory feedback helped reinforce learning through sound.

The results showed that the prototype can effectively engage children (92% of the participants agreed), providing an enjoyable and interactive experience. The game-based learning approach, which integrates sensory feedback through touch, sound, and sight, was particularly well-received, with users appreciating the combination of learning and play. This aligns with research suggesting that game-based learning can increase motivation and retention, making it an effective tool for early literacy education.

The integration of a serious game component in the multisensory tangible game device proved to be a valuable approach for engaging children in the learning process while supporting pre-Braille literacy. The serious game aspect of the prototype successfully blended educational objectives with interactive play (75% of the participants agreed), fostering a sense of enjoyment and motivation among the children.

In conclusion, the multisensory tangible game device shows promising results as a tool for inclusive pre-Braille literacy. By integrating multiple sensory modalities, it provides a dynamic and interactive learning experience that accommodates the needs of children with varying visual abilities. The positive response received by the prototype, combined with constructive feedback for refinement, provides a strong foundation for further development.

8.2. Future Work

According to the insights gained from the focus group, valuable guidance is provided for the next stages of development; we have plans for subsequent validation tests with children, and incorporating more adaptive features, such as adjustable difficulty levels according to the student’s level of Braille literacy knowledge, will ensure that the device can grow with the users and continue to meet their educational needs as they progress. Additionally, the prototype’s ability to foster inclusivity between sighted and visually impaired children is a significant strength that should be further emphasized. According to

users' opinions, the device's capacity to engage users across varying levels of visual ability was highlighted as one of its strongest features to be improved on, fostering an inclusive environment for both visually impaired and sighted children.

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