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Research and Technology for the Social Inclusion of People with Hearing Impairment

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Abstract

People with hearing impairments face challenges that affect their communication and social inclusion. Sign language is a key communication system that improves the level of social inclusion of the hearing-impaired population. To address this, our collaborative work aims to develop a technological tool that enhances the initial learning of sign language in children with hearing impairments. This tool, developed with the use of information and communication technologies and the advice of professionals in special education, is designed to specifically facilitate the learning of sign language in deaf children. Our tests have demonstrated its effectiveness, with a 30% reduction in the initial learning time of sign language in deaf children.

Keywords: *communication, hearing impairment, learning, technology, sign language, social inclusion.*

Introduction

People with hearing impairments face unique challenges that affect their communication and participation in society (Putri et al., 2025; Subashini et al., 2024). Hearing loss can vary in degree, from mild to profound, and can be congenital or acquired throughout life (Chiaramello et al., 2015; Saran et al., 2025). These challenges involve difficulties in hearing sounds, accessing information, and participating fully in social, educational, and work interactions (McDaid et al., 2021). However, people with hearing impairments have developed various communication strategies, such as sign language, lip reading, hearing aids, and assistive technology, to overcome barriers and lead active and productive lives (Fernández Batanero et al., 2022; Patel et al., 2025). It is essential to foster greater social awareness of their needs and rights, promoting inclusion and accessibility in all areas of life (Uluer et al., 2023). Respect for their cultural and linguistic identity, as well as creating more accessible environments, are essential steps to ensure equal opportunities for people with hearing impairments (Abou-Abdallah & Lamyman, 2021; Bott & Saunders, 2021).

Sign language is a visual and gestural communication system used by deaf people to express thoughts, emotions, and ideas (Abduzuhurovna, 2022). Unlike oral language, it is based on a series of signs made with the hands. It also incorporates facial expressions, body movements, and the spatial position of signs to convey full meanings (Mohr & Bauer, 2022; Mora et al., 2021; Othman, 2024a). Each deaf community develops its sign language, giving rise to regional variations, such as Mexican Sign Language (LSM), American Sign Language (ASL), and many others (Othman, 2024b). This language is not a simple translation of a spoken language but a complex and structured form of communication with its vocabulary, grammar, and syntax. Sign language is fundamental not only for the accessibility of the deaf community but also for promoting a deeper understanding of linguistic and cultural diversity, reinforcing inclusion and respect for differences in society (Hodge & Goswell, 2023; Kusters & Lucas, 2021).

Developing technologies that facilitate sign language learning is vital to promoting the inclusion and accessibility of deaf people in society (Talaat et al., 2024). In an increasingly interconnected and digital world, technology offers innovative tools that allow users to learn and practice sign language in a more effective and personalized way (Papatsimouli et al., 2023). These technologies help overcome communication barriers and contribute to the visibility and recognition of sign language as a legitimate and valuable communication system (Almufareh et al., 2024; Haleem et al., 2022; Papatsimouli et al., 2023). Interactive platforms, mobile applications, and artificial intelligence-based systems can provide instant

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feedback, adapt to the learner's needs, and allow for a deeper immersion in deaf culture, which is essential for effective communication and developing greater empathy and social understanding (Nakamura & Jing, 2025). Thus, integrating these technologies represents a crucial step toward building a more equitable and accessible society for all (Haleem et al., 2022).

Although deaf people do not have any intellectual or cognitive limitations, it is essential to have specialized services to ensure adequate education (Almomani et al., 2021; Larsen & Dammeyer, 2021; Leigh et al., 2022), such as sign language interpreters, subtitled videos and films, among others. In addition, it must be considered that deaf children will face more significant difficulties in learning vocabulary, expressions, the order of letters in the alphabet, and other aspects related to communication (Leigh et al., 2022). Therefore, it is crucial to employ visual communication methods from an early age, such as sign language, manual alphabet, and supplemented speech (Alothman, 2021; Bintoro et al., 2023; Kourbetis & Karipi, 2021; Wainscott & Spurgin, 2024). Both parents and teachers play an essential role in this learning process since their collaboration will allow for continuous development and the achievement of annual goals under the constant support of teachers and family members (Almomani et al., 2021; Bintoro et al., 2023; Larsen & Dammeyer, 2021).

Starting with the research question, how could technology improve the social inclusion of people with hearing disabilities, allowing them more significant opportunities? Education and quality of life? To solve this problem, the present work aims to design an application that increases the level of autonomous learning and reduces the learning time of sign language in deaf users, especially children. Additionally, it facilitates communication with hearing people who do not know sign language through a voice synthesizer and a voice recognition module. The *EnSeña App* will be developed on the Android platform (v4.0 or higher) and installed on digital tablets and smartphones.

Related Works

Communication represents a significant challenge for people with hearing loss, as it limits their participation in social, educational, and work environments. In this context, sign language interpretation has been the subject of numerous recent studies to reduce the communication gap with the hearing population.

One of the most explored proposals is using artificial intelligence for automatic sign language translation. Image-based recognition has seen significant advances thanks to the development of deep learning. However, one of the main limitations in this field is the difficulty in collecting representative data, which generates insufficient or imbalanced data sets. To mitigate this problem, data augmentation has been used as a common strategy, although it is usually implemented independently of model training, making joint optimization of parameters difficult. In response to this limitation, approaches that integrate data augmentation within the learning process have emerged. For example, (Nakamura & Jing, 2025) propose the Adversarial Vulnerability-Seeking Networks (AVSN) method, which allows generating synthetic adversarial data designed to challenge the recognition model, strengthening its learning capacity and reducing overfitting. AVSN is especially useful in scenarios with limited sign language data sets, such as in poorly documented sign languages or specialized vocabularies.

In particular, deep learning models have shown high potential in real-time sign recognition and generation. (Talaat et al., 2024) Present a real-time avatar system to facilitate communication between people with hearing loss and the hearing population. This system uses deep learning models to translate text or spoken input into sign language movements. The dynamic generation of the avatar movements allows for fluid and organic communication in real time. This technological solution not only improves accessibility for the hearing-loss population but also represents a significant advancement in implementing interactive avatars that can facilitate communication in different sign languages.

Traditionally, sign language learning has been approached through educational books and videos; however, these methods have limitations due to the lack of real-time interaction and feedback. To overcome this barrier, interactive systems based on computer vision and machine learning technologies have been developed, allowing more dynamic and personalized teaching. An example of these innovations is the

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proposal by (Zhang et al., 2021), who developed a mobile application that captures and analyzes the user's gestures using the device's front camera, thus facilitating an objective and subjective evaluation of their performance. This proposal incorporates point cloud recognition, allowing for the accurate identification of signs in real time. These technological advances improve the learning experience and expand access to sign language education.

Although there are books and online repositories with sign language representations, most of these lack an organized structure or contain a small number of videos, making it difficult to use them as practical learning tools. Recent research has explored technological solutions to improve accessibility and study. To address this situation, (Ramírez-Noriega et al., 2024) propose a Collaborative Web System that allows searching for sign language videos from text input. The platform facilitates access to dynamic visual material and promotes the participation of the hearing and hearing community in building a collective knowledge repository. The usability evaluation showed that these systems can improve the learning experience, although they still present opportunities for improvement. In this context, collaborative web applications emerge as a promising alternative to strengthen the teaching and dissemination of sign language, contributing to more inclusive communication.

Sign language learning has sparked increasing interest among hearing people, highlighting the need for practical teaching tools. One of the main challenges in this process is students' difficulty identifying errors in their movements; intervening with an expert to provide objective feedback is essential. In response to this need, (Iwasako et al., 2014) have explored self-learning systems that allow users to improve the accuracy of their gestures autonomously. To do so, they combine data gloves with 3D models, making it possible to superimpose the student's movements with those of an expert user. This type of system represents a significant advance in sign language teaching by providing an interactive self-assessment tool.

Problems in the Interaction of the Deaf

The fact that the deaf person cannot hear his surroundings from his first years of life dramatically hinders communication, imitation of sounds from his immediate environment, and learning oral language by imitation. By not having immediate information about his environment in everyday situations, the deaf person will often have an erroneous understanding of his environment, oral explanations about emotions, and facial expressions of the person trying to communicate with him.

Because his interaction with others is made difficult by the existing language barrier, he is frequently asked to obey the orders of his parents or caregivers without being told the cause of the action he is being ordered to perform, which contributes to the deaf person not understanding the why of things, the complexity of actions, among others. As a result, he may adopt attitudes of insecurity, rebellion, and impulsiveness. The consequence of all this is that the deaf person will not know or will not understand the rules well, and his behavior will sometimes be inappropriate (Fernández-Viader & Pertusa Venteo, 2005).

In the interaction with parents, it is worth differentiating the relationship between deaf parents and deaf children and the relationship between hearing parents and deaf children. In the first relationship, it can be observed that both parents and children use sign language, which allows for a more complimentary interaction on the part of the child since he can develop more advanced communications with his parents, enriching his language and understanding of the world (Rondal, 1984). In contrast, in the relationship between hearing parents and deaf children, the parents take the initiative in the interaction with their child, which is restrictive, not allowing the child to behave freely and in a certain way inhibiting his initiative (Lederberg & Everhart, 2000). In general, the options given to people who are deaf or hard of hearing are closed; that is, they are not shown various alternatives, such as for example: Are you going to do this activity or that? Are you going to play with this or that? Among others?

Since there is no language of common understanding for both parties, the possibility of formulating questions of greater complexity or that involve more abstract ideas, such as thinking about the future or the perception of people, is avoided. Consequently, people who are deaf or hard of hearing cannot understand the temporal sequences and, therefore, plan projects in the medium or long term (Echeita, 2016).

If the relationship between hearing parents and deaf children becomes very controlling, an expression of rebellion may arise, which would not facilitate the learning process. On the other hand, if the parents are too flexible with the child, it may generate in him a behavior of immaturity and egocentrism by making decisions without parental control.

These immature behaviors are generated by the child's relationship with his or her parents. Starting from the fact that the parents do not encourage spaces for interaction with the deaf child due to the lack of mutual understanding, the interaction will tend to decrease due to the parents' frustration of not finding a response in the child to verbal initiatives, whether from the father or the mother.

In the previous context, the deaf person brings with him a communication barrier from his family environment, which makes it even more complex for him to communicate with others; frequently, he perceives that he is not understood or that he does not fully understand what the other person is saying to him. He is aware of the uncomfortable reactions of others and perceives that the dialogue is reduced or canceled.

Returning to the relationship of deaf parents with their deaf child, the latter develop better self-esteem and self-concept due to their fluid interaction with their parents. They have role models with whom they feel fully identified and want to be like their parents. They can develop ideas, not only in the short term, but they can project them into the future (Adams, 2012; Fernández-Viader & Pertusa Venteo, 2005). All these advantages are made possible thanks to communication support tools such as:

- Sign language.
- Family integration with a shared communication system.
- Please provide feedback to the deaf person according to their behavior and reactions.
- Give the deaf person freedom to express their ideas spontaneously and without limiting them.
- Create many quality spaces for interaction with the deaf person.
- Regulate their behavior appropriately.
- Provide prior information on rules, dangers, and conduct to follow.

Problems in the interaction of the deaf person outside their family environment

The interaction of the deaf person outside their family environment, with their peers, is usually not very flexible, not very structured, sporadic, simple, brief, and referred to aspects of the "here and now." Many hearing people with deaf classmates in their classes do not know how to communicate with them because they do not have mastery and/or knowledge of sign language. This is why many hearing people are unaware of the effects of deafness and maintain myths and stereotypes about their deaf classmates.

Because of this poor social interaction, the deaf person develops fears, insecurity, withdrawal, and low self-esteem caused by:

- There is an absence of a standard communication code between hearing and deaf people.
- The lack of information and experience.

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- Inappropriate attitudes of others.
- Impoverished and often non-existent interactions.
- Society's exclusion from the deaf community is due to not knowing how to interact with them.

Implications of interaction in the education of the deaf

It is very important that the problems of interaction that the deaf have with their family and social environment are considered in the education of the deaf. The starting point must, therefore, be generated from within the family. For this reason, an educational intervention must be carried out not only for the deaf person but also for all members of their family, instructing them in sign language.

To improve the linguistic skills of the deaf, family members must provide them with information that progressively becomes more elaborate and complex, as far as their age allows, to enhance their communication capacity. Likewise, they must know their environment in detail to better understand it and understand the actions that occur around them so they can behave more coherently in certain situations.

They must receive treatment like their peers, avoiding exceptions at all costs and normalizing treatment. In order to foster confidence in the deaf, it is advisable that the hearing person not always provide help to the deaf person but that the latter have spaces where he can assume responsibilities and be the spokesperson for information or explanations for his companions (Bott & Saunders, 2021; McDaid et al., 2021; Putri et al., 2025).

Hearing children in the company of deaf children must be instructed on the effects of deafness and trained in communication systems such as the bimodal system and the complemented word, among others. Promoting the learning of sign language in deaf children makes it easier and more motivating for the child to learn to read and write. This would be an important benefit for the deaf child since he would have more significant sources of information at his disposal. In the specific case of this project, he could use the voice synthesis module to communicate with people who have not been instructed in sign language.

Technological Tool Design

The design of this technological development focused on an easy-to-understand and manage sign language learning tool for deaf children aged 2 to 12 so that they and their parents have a more interactive approach to sign language and can become familiar with it more easily. In addition, the prototype must be a portable element, allowing the deaf person to carry it with them at all times. See Figure 1.

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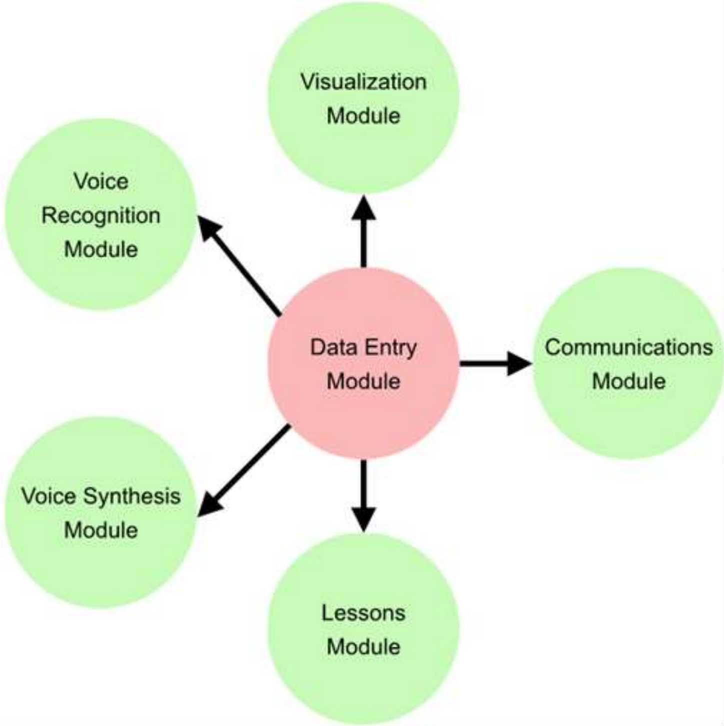

Figure 1. Block diagram of technological development

Data Entry Module

The design of this module consists of a touch-sensitive graphic screen with which the user can select each of the technology's menus. The touch-sensitive graphic screen centralizes all the prototype's available functions, and the user can interact with all of them from it.

Once the prototype is powered up, a welcome message is displayed, and four menu options are displayed available to the user:

- ✓ Lessons Menu
- ✓ Communication Menu
- ✓ Graphic Communication Menu
- ✓ Voice Recognition Menu

Lessons Module

The system displays the lessons in the prototype when the user selects the Lessons menu option:

- ✓ Letters
- ✓ Numbers
- ✓ Months

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- ✓ Days
- ✓ Colors
- ✓ Greetings
- ✓ Expressions
- ✓ Clothing
- ✓ Family

Display Module

This module uses the touch screen provided in the prototype and focuses on the Lessons menu, where the greatest interactivity between the user and the system occurs. When the user selects the Lessons Menu option, the system displays the lessons available in the module.

Communications Module

When the user selects the box representing the Communications menu, the tool displays a new screen. It enables a QWERTY keyboard at the bottom of the screen and a blank space at the top of the screen to display what the user writes before it is sent to the voice synthesizer.

Voice Recognition Menu

When the user selects the box representing the Voice Recognition menu, the prototype displays a new screen that includes the start and exit keys and a space within this screen called "Lesson," where the word recognized by the module is displayed.

Voice Synthesis Module

It consists of converting text entered by the user using a keyboard generated on the screen into voice so that the user can express his or her ideas and/or concerns to hearing people.

Design of the EnSeña Application

The following requirements were established for application design:

- **Use of fragments:** The application must manage different interface sections within a single activity. This allows multiple panels to be displayed and fragments to be reused in different activities, thus optimizing navigation and design.
- **Incorporation of an action bar:** The action bar must fulfill three key functions: provide a visible space throughout the application that reinforces its identity, facilitate quick access to important actions, and ensure consistent navigation with fluid view changes.
- **Implementation of a *Navigation Drawer*:** This component is ideal for applications with more than three main screens, as it allows efficient navigation between intermediate levels and facilitates access to main sections, even in structures with deep branches.
- **Integration of an online voice recognition library:** A library must be used that allows real-time voice processing and recognition, improving user interaction with the application.

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- **Communication module:** A module capable of converting the text the user enters phonemes must be implemented, facilitating communication through the device.

- **Video playback:** Since teaching sign language is a fundamental aspect of the application, it must have a video playback function that reinforces learning and understanding of signs.

With the established requirements, the App was designed.

Application Development

The project created for Android Development is called Atplis, which stands for *Audition Technologies for Social Inclusion*. The structure can be seen in Figure 2.

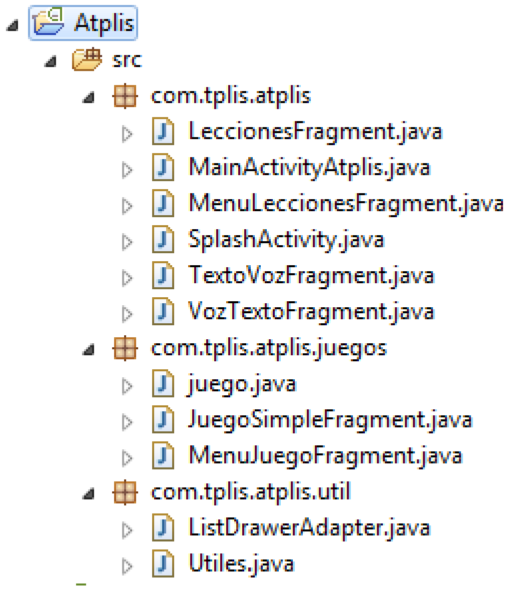

Figure 2. Development packages and classes

The main components of the application are described below (see Figure 2):

- **SplashActivity.java:** This is the *launcher* activity configured in the *Manifest* to run when the application is opened. This activity keeps a thread active for three seconds before starting *MainActivityAtplis.java*, applying a fade animation.

- **MainActivityAtplis.java:** This activity controls the *Navigation Drawer* and manages the application's main flow. It loads the resources for the buttons, the *ListView*, and the titles used in the *Navigation Drawer* and the *ActionBar*.

- **MenuLeccionesFragment.java:** Displays the menu of the eight available lessons. Each lesson is represented by a button that, when pressed, can be heard by the user. When selecting an option, the fragment is replaced by *LeccionesFragment.java*, sending it the parameter of the chosen lesson.

- **LeccionesFragment.java:** This function receives the parameter of the selected lesson and loads the list of available options in the database associated with videos. It then displays a *ListView* with these options and a *VideoView* to play sign language videos. When the user selects an option, the corresponding video is displayed from the application resources.

- **MenuJuegoFragment.java:** Presents the evaluation menu for the eight lessons using a game. Each lesson is represented by a button that, when pressed, can be heard by the user. When selecting

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an option, the fragment is replaced by JuegoSimpleFragment.java, sending it the parameter of the chosen lesson.

- JuegoSimpleFragment.java: Receives the parameter of the lesson to be evaluated and loads a list with all the possible options. It displays a ListView with these options and a VideoView in which four signs appear that the user must identify. The game logic and the calculations of questions and answers are managed in a separate class: Juego.java.
- **TextoVozFragment.java:** This fragment provides an interface with an *EditText* where the user enters text that the application converts into speech. This fragment controls the keyboard's visibility and uses the *TextToSpeech* object, configured to read the entered text in the language set on the device.
- **VozTextoFragment.java:** This file presents an interface with an *ImageView* of a microphone, which the user can press to activate the speech recognition functionality. It also includes a *VideoView* where the video of the pronounced sign is played and a *TextView* that shows the text corresponding to the recognized sign.

Evaluation of the EnSeña Application

The evaluation was conducted through a pilot test at the Institute for Special Therapy of the Senses (ITES) of the Lions Club of Cali San Fernando, Colombia. A 13-year-old pre-adolescent, two boys aged 9 and 6, and a 9-year-old girl, belonging to the pre-kindergarten, first, second, and third grades of primary school, participated.

Two instruments were used to collect data. The first of a quantitative nature consisted of analyzing the statistical data recorded and stored automatically by the application in each learning session. These data were saved in the tablet's memory through operating logs.

The second instrument was qualitative and corresponded to the non-participant observation technique. In this technique, the tablet with the application was given to the user, and its intuitive use and the learning acquired through interaction with the tool were evaluated.

The results of the quantitative evaluation are presented in Table 1.

Table 1. App usage statistics

Total Time (min)	Topics Viewed	Time per topic viewed (min)	Assessments Applied	Average Evaluation
2.03	1	2.03	1	25
130.33	7	18.62	3	75
23.05	6	3.84	0	NA
5.67	5	1.13	0	NA
5.97	3	1.99	0	NA
3.05	1	3.05	0	NA
38.32	4	9.58	0	NA
19.30	6	3.22	4	625
6.47	2	3.23	2	87.5
0.83	1	0.83	0	NA

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Total Time (min)	Topics Viewed	Time per topic viewed (min)	Assessments Applied	Average Evaluation
37.77	3	12.59	0	NA
23.32	9	2.59	10	27.5
4,87	2	2,43	0	NA
5,58	2	2,79	1	0

The data obtained in the logs, presented in Table 1, determined that the average total time of use was 21.9 minutes, with a standard deviation of 33.74 minutes. The average time per topic viewed was 4.85 minutes, with a standard deviation of 5.13. The total average evaluation reached a value of 36.875.

These results suggest that the application is not entirely intuitive for users, which is also reflected in the scores obtained in the evaluations. This could indicate that, as it is aimed at minors, its design requires the accompaniment of a teacher for its use. Consequently, the application works as a learning support tool but not a resource for autonomous learning.

The results of the qualitative evaluation based on the observation technique were the following:

- **6-year-old girl (pre-kindergarten):** She had difficulty decoding the signs due to the absence of illustrations, as she does not yet recognize graphemes. However, she showed interest in continuing when identifying familiar numbers within their immediate context.

- **9-year-old girl (first grade):** She understood the program's objective and correctly manipulated each section. However, she had difficulty self-assessing herself due to her initial stage in the reading and writing process and the differences between the signs in the program and those she already knew.

- **9-year-old girl (second grade):** She actively participated and showed enthusiasm for the activity but expressed dissatisfaction because the signs on the device differed from those in her region. She corrected some of them and explained how she had done them.

- **13-year-old pre-adolescent (third grade):** Although she imitated the signs, she did not understand the association with the graphemes. She made sounds for voice recognition, but the device did not identify them correctly. As for written communication, he responded favorably and efficiently handled the device. However, the lessons' vocabulary made communication difficult, as they included terms foreign to his regional context.

Several aspects to consider in the *EnSeña App* were identified based on the results obtained. First, it is essential to adapt the vocabulary to the different regions where the communication device will be implemented, ensuring greater accessibility and understanding for users.

In addition, it is recommended that both the vocabulary and the lessons be expanded since the current content is fundamental and can create barriers to communication. To improve the learning of the deaf population, it would be beneficial to incorporate images that represent the signs, allowing a better association between image, written word, and sign.

On the other hand, the alternative communication device is designed primarily for people with hearing loss who use oral language. Finally, it is suggested that the program incorporates standardized signs at a general level, avoiding confusion among students and facilitating their understanding.

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Learning time

To measure learning times, the advice of a professional in the area was used. The professional made available the students in their last semester of Early Childhood Education who have hearing disabilities and use sign language to communicate.

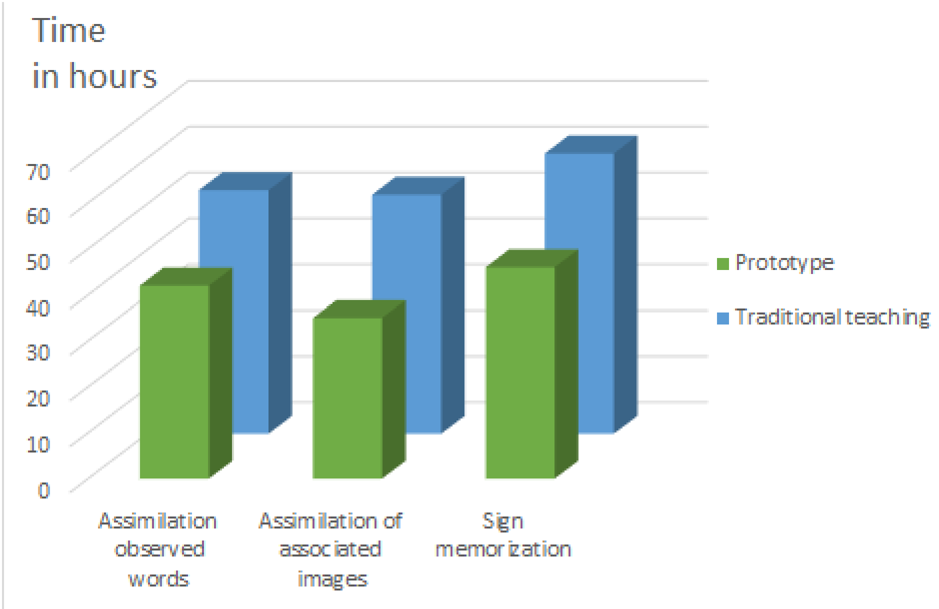

Figure 3. Learning time results

Through theoretical and practical meetings, the following results were reached: The maximum time for the child to successfully imitate the gesture reproduced in the video using the technological tool is approximately three minutes, depending on the complexity of the sign, which implies repeating the video between four and seven times. However, it should be noted that a more prolonged process is required to conclude that the child effectively memorized the translation into signs of the represented word.

The average learning time of the words available in the prototype was measured and compared with the traditional learning method, resulting in Figure 3.

Conclusions

The technological proposal developed is a complementary tool that helps reinforce the sign language learning process, generating autonomy in the study by the device's users and achieving a synergy between pedagogy and technology. From this perspective, the project contributes to solving the problem of social inclusion to which people with hearing disabilities are exposed in Colombia.

This development can be used by people with or without hearing disabilities who wish to acquire knowledge of sign language. For deaf people, the device constitutes a basic learning tool and a possibility of communication. In contrast, for hearing people, it constitutes a didactic tool for learning sign language to communicate with deaf people. People who used the device stated that it is a useful technological tool for learning sign language and that, thanks to its interface, its manipulation was much easier.

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