Journal of the Academy
Asociación de Universidades del Perú, Lima, Perú.
ISSN 2707-0301
Núm. 14. Enero-Junio 2026
http://journalacademy.net/

MANAGEMENT OF TECHNOLOGICAL TOOLS FOR LEARNING SIGN LANGUAGE

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Received	:	02/12/2025
Approved	:	11/03/2026
Published	:	24/06/2026

ABSTRACT: Learning sign language is an essential component for promoting inclusion and communication in educational settings. At the María Doraliza Educational Institution in the Riohacha District, the need to strengthen autonomous sign language learning by integrating accessible, innovative technologies was identified. This article aims to identify the most effective technological tools for learning sign language, based on the project "Technological Tools for Autonomous Sign Language Learning at the María Doraliza Educational Institution." The methodology employed was qualitative-descriptive, grounded in document review, analysis of pedagogical experiences, and observation of inclusive practices mediated by ICT. The findings demonstrated the potential of tools such as HandSpeak, Incluseñas, SignaTalk, and mobile applications that integrate artificial intelligence, augmented reality, and interactive videos. These tools strengthen understanding of gestures, foster autonomous learning, and promote inclusive education. It is concluded that the use of ICT in sign language learning facilitates participation, improves accessibility, and strengthens awareness of communicative diversity in educational settings. Furthermore, it offers a practical, context-based solution that transcends theory. While most studies focus solely on inclusion, this study offers a strategic selection of tools (HandSpeak, Incluseñas, and SignaTalk) tailored to the Riohacha context. It also aims to transform technology from a passive tool into an active educational agent that ensures deaf students the right to independent learning and helps hearing students develop empathetic communication skills, thereby helping to overcome barriers of silence in the classroom.

Keywords: Sign language, technological tools, educational inclusion, autonomous learning, TIC.

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INTRODUCTION

Sign language is one of the fundamental pillars of human communication, as it allows deaf people and sign language users to express themselves, understand their surroundings, and fully engage with the world. It is not merely a set of gestures or movements, but a complete linguistic system with its own grammar, vocabulary, and syntactic structure. Its recognition as a natural language in various countries, including Colombia, represents a significant step toward respecting linguistic rights and building a truly inclusive society, as "It is difficult to have an inclusive school in an exclusive society" (Marzo Peña et al., 2022).

Despite its communicative and cultural value, the teaching and learning of sign language face multiple challenges in the educational sphere. In many institutions, traditional methodologies fail to meet the needs of deaf students or hearing students who wish to learn it. In this regard, an enriching form of instruction is considered necessary. This involves diversifying resources and supports to align with the multiple forms of diversity currently observed in educational contexts (González Encalada et al., 2024). Limitations in educational resources, a shortage of qualified interpreters, and a lack of accessible strategies hinder its integration into the school curriculum and perpetuate communication barriers that obstruct inclusion. Colombian Sign Language (LSC) is not merely a form of communication for the deaf; it is a language and a cultural heritage. The Citizen Security Law protects physical integrity and guarantees civil rights. Yet traditionally, this community has been excluded from education and technology. The lack of tools and platforms to develop visual interfaces accessible to people with disabilities constitutes a "second barrier" to inclusion: digitalization. This inequality deepens school segregation and reduces employment and personal opportunities in an increasingly inclusive world.

Proficiency in American Sign Language (ASL) is vital for deaf and hearing-impaired individuals. The only way to break down communication barriers is for the speaker to communicate in sign language; thus, the responsibility for inclusion falls on everyone as a right, not merely as an obligation of the hearing person. Technology is not only a tool for deaf people to participate in the hearing world, but also a channel for equitable and autonomous access that democratizes the world.

Against this backdrop, technological tools emerge as a transformative alternative that expands the possibilities for access, practice, and learning of sign language. According to Lozada et al. (2024), these tools are essential for optimizing and refining these processes. Information and Communication Technologies (ICT) offer dynamic, visual, and interactive environments that align with the gestural and visual nature of this language, enabling more autonomous and meaningful learning. In this sense, technology serves as a bridge between traditional and inclusive education. Advances in educational technologies, particularly the use of digital platforms, mobile applications, and systems based on artificial intelligence, have enabled the design of specialized resources that facilitate teaching and learning in virtual environments (Area and Adell, 2009; Lozada et al., 2024). When applied to sign language, these technologies enable the development of applications that integrate visual resources, gesture recognition, and real-time feedback, thereby promoting students' comprehension and independent practice (Quevedo-Sánchez et al., 2025). In this sense, digital environments contribute to the democratization of learning by expanding access to education without restrictions on time, place, or socioeconomic status (Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura [UNESCO], 2024).

Apps such as HandSpeak, Incluseñas, and SignaTalk incorporate visual elements, gesture recognition, and real-time feedback, which promote students' progressive understanding and consistent practice of sign language. In this sense, these digital environments contribute to the democratization of learning by making sign language available to anyone interested, regardless of their geographic context or socioeconomic status (Area and Adell, 2009). In line with this perspective, the María Doraliza Educational Institution in the District of Riohacha is an ideal setting for analyzing this reality, as its school community brings together hearing and deaf students who seek to communicate effectively and respectfully. However, the lack of adapted technological resources and limited teacher training in the use of inclusive digital tools restricts the development of communication skills in sign language, highlighting the need to strengthen technology-based pedagogical strategies.

In summary, the purpose of this article is to analyze the technological tools that facilitate the learning of sign language and to highlight their importance in building a more accessible,

equitable, and modern education system. Identifying and leveraging these digital resources marks a turning point in inclusive education, where hands-on digital screens become symbols of communication, empathy, and social transformation.

Like any scientific inquiry, this analysis has certain limitations. Among these considerations, the qualitative and descriptive nature of its findings in Riohacha prevents their generalization to isolated rural contexts or educational institutions lacking infrastructure. Additionally, the analysis is limited by the obsolescence of certain digital applications and by educators' insufficient technological skills, factors that could jeopardize the effectiveness of the identified tools if they are not integrated into an institutional training process. Furthermore, there is a logical connection between the social demand for inclusion and the pedagogical response supported by Information and Communication Technologies. Consistency is observed between the communicative issues proposed in the introduction, the theoretical frameworks of learning democratization, and the final selection of tools such as HandSpeak and Incluseñas. This contribution is essential to the study, given that each section of the manuscript is not perceived as an isolated entity, but rather as a key element in arguing why technology constitutes the most effective instrument for modifying the curriculum of the María Doraliza Educational Institution toward a model of global accessibility.

BACKGROUND

From a theoretical perspective, the relationship between technology and inclusive learning is grounded in the digital constructivism paradigm, which promotes active student participation through meaningful experiences mediated by technological tools (Jonassen, 1999; Coll, 2004). The incorporation of visual, audiovisual, and interactive resources fosters autonomous and collaborative learning, allowing students to construct their knowledge at their own pace, with immediate feedback, and in motivating environments (Area and Adell, 2009). Internationally, in the Dominican Republic, De Jesús-González et al. (2023) show that this represents a challenge for students with hearing impairments and for teachers, due to constraints that make it difficult to ensure adequate learning. A solution project is proposed

to detect technical sign language in cross-curricular education, using a technological tool that facilitates its documentation and definition in the field of economics.

Based on these findings, the website interface was designed to include start, pause, and navigation buttons, as well as an appropriate color palette and a clear definition of the various challenges that the player/learner must overcome in each module to achieve the objective and complete the cross-cutting entrepreneurship competency. To simplify user access, the interactive content was exported to a web platform using the Unity 3D game engine. In this environment, the character, its animations, and the different levels were developed in an inclusive and interactive manner for all participants, along with the creation of various test scenarios that integrated videos, animations, and options for manipulating objects (De Jesús-González et al., 2023). As part of this process, the technical and basic vocabulary of cross-curricular entrepreneurship was recorded for representation in Colombian Sign Language, with the participation of cross-curricular entrepreneurship instructors and a sign language interpreter, which ensured the conceptual and linguistic relevance of the designed material (González Vanegas et al., 2025). Likewise, the correct interpretation of the phrases was verified with interpreters and learners with hearing impairments, thereby facilitating collaborative validation of the content from an inclusive education perspective. Finally, gamification technology was implemented by incorporating the digital content created for each module of the entrepreneurship cross-curricular program into the platform, using the interface designed for validation by the end user, with the aim of increasing learners' motivation, active participation, and autonomous learning (Kapp, 2012; Deterding et al., 2011).

By highlighting the importance of research in addressing similar challenges in your specific context, this study serves as a model for using technology to overcome communication barriers in the education of deaf individuals through accessible, tailored digital resources (Marschark et al., 2019). Thus, it reaffirms the relevance of your emphasis on seeking innovative and affordable solutions to overcome communication and educational barriers in your community, in line with inclusive education approaches and the pedagogical use of ICT

to promote the participation and meaningful learning of students with hearing disabilities (UNESCO, 2017; Moreno-Rivera and Agudelo-Velásquez, 2016).

In turn, in the United States, in the journal Frontiers in Education, the authors Rodríguez-Correa et al. (2023) argued that technologies have expanded digital access to many everyday activities. Various tools have been created to benefit people with specific needs, such as deaf sign language users who require inclusive technologies to communicate in the workplace, educational settings, and social contexts.

The purpose of this research is to identify assistive technologies that improve communication between deaf and hearing individuals. To this end, a systematic review was conducted following the PRISMA checklist in databases such as Scopus, Web of Science, and PubMed. A total of 492 documents were identified, and inclusion and exclusion criteria were applied; of these, 27 were included in the quantitative synthesis. As a result, the research identified gesture recognition technologies to translate sign language into speech and vice versa, technologies for teaching sign language, technologies for automatically generating captions, web-based technologies, and technologies based on text and light networks. The results indicate that further research is needed on the motivations for developing sign language technologies to include deaf communities in society without linguistic impositions.

Similarly, in Ecuador, Córdova Guerrero (2022) proposed developing a program for sign language teachers to address the need to strengthen inclusive communication between people with hearing impairments and the deaf community, particularly in mainstream educational institutions.

The participants' experiences were investigated through interviews; subsequently, a theoretical framework was developed to address the most significant aspects of the deaf community, teachers' training needs, and inclusive communication for students with hearing impairments. This research highlights the importance of equipping teachers with the necessary skills for effective communication. It also reaffirms the importance of creating a platform and utilizing digital resources that promote self-directed learning, demonstrating that this approach is effective and scalable. Similarly, it suggests that the challenges and solutions identified in a Latin American country may be applicable and serve as a reference

for other contexts, such as Colombia. Furthermore, it offers solid academic support for implementing programs and methods to include people with hearing disabilities, validating the relevance of this perspective and providing a framework for understanding the benefits of these projects in higher education (Córdova Guerrero, 2022).

In Colombia, Martínez-Acosta et al. (2022), in their study titled "Mobile App as a Teaching Strategy to Initiate the Reading Process in Students with Hearing Impairments," evaluated the impact of a mobile app on the academic performance of these students throughout the educational process. This tool was designed to support the development of reading skills in this population.

This app promotes the study of vowels, consonants, and lessons through content review and a variety of activities, all presented in LSC, which facilitates grapheme recognition, phonological association, and the strengthening of literacy skills in students with hearing impairments (Sastre-Gómez et al., 2017; Oviedo, 2001). The grades obtained by 45 students in grades 1, 2, and 3 of elementary school are examined using a factorial design experimental study, with the aim of analyzing the effect of the intervention mediated by accessible educational technologies on academic performance and the learning processes of reading and writing (Moreno-Rivera and Agudelo-Velásquez, 2016). The findings indicate that strategies have a considerable impact on learning and that differentiated tasks promote better knowledge assimilation, to the extent that they respond to the specific characteristics, paces, and needs of each student (Tomlinson, 2014; Díaz-Barriga and Hernández Rojas, 2002). It follows that, to enhance the reading and writing learning process for students with hearing impairments and improve their academic performance, it is essential to develop content and tasks that align with their learning styles, incorporating visual resources, multimodal supports, and curriculum adaptations that facilitate access to knowledge and active participation in the classroom (Marschark and Spencer, 2010).

By addressing challenges and solutions within a geographical and social context similar to our own—which facilitates comparison and enhances the relevance of the findings—this type of research demonstrates how digital technologies can be adapted to local realities to meet the educational needs of the deaf community. It demonstrates the effectiveness and feasibility

of these digital solutions in increasing access to and the quality of education for the deaf community by offering visual, interactive, and accessible resources that strengthen teaching and learning processes (UNESCO, 2017). Furthermore, it reinforces the idea that tailored technological solutions are an effective means of significantly enhancing the education and inclusion of people with hearing disabilities, provided they are developed with the participation of the users themselves and integrated into inclusive and sustainable pedagogical practices (Moreno-Rivera and Agudelo-Velásquez, 2016). Similarly, in Colombia, Palomino et al. (2022), in their study titled "Design and Production of an Educational Audiovisual Series as a Teaching Strategy in the Instruction of Colombian Sign Language," note that in recent years the country has implemented various measures aimed at strengthening the quality of education for people with disabilities.

This paper presents the development and production of an educational audiovisual series as a pedagogical strategy for teaching Colombian Sign Language (CSL), describing the methodology used and each of its phases, in line with approaches that incorporate audiovisual resources as a central support for learning sign language (López Gómez, 2020; Oviedo, 2001). Among the results obtained, three videos stand out, covering the topics of the Colombian finger spelling alphabet, emotions, and colors. These were produced using various audiovisual techniques and tools appropriate to the nature of the subject matter and supplemented with educational and pedagogical components derived from the recommendations of specialists in the field of sign language learning, prioritizing visual clarity, gradual content presentation, and accessibility for students with hearing impairments (De Jesús-González et al., 2023). This work is presented as the beginning of a series of videos related to essential topics for learning LSC. Furthermore, it offers a geographical and linguistic context highly relevant to its study, which facilitates the identification of parallels and the derivation of lessons applicable to one's own reality. Similarly, it supports the notion that audiovisual media are effective for learning LSC (Palomino et al., 2022). It also supports the feasibility and relevance of your approach to incorporating technologies to promote independent learning and inclusion in education.

In the case of sign language, ICT-mediated self-directed learning promotes the continuous practice of gestures, expressions, and communicative structures. Students can observe, imitate, record, and correct their own movements, which reinforces visual memory and motor precision—fundamental aspects for the development of communicative competence within the deaf community (Oviedo, 2001). This process becomes a multisensory experience in which technology acts as a virtual tutor, facilitator, and motivator of learning by offering immediate feedback and dynamic visual resources that strengthen the autonomous construction of knowledge (García Rivera and Céspedes Guevara, 2025). The implementation of these tools has not only a pedagogical impact but also a social and cultural one. As more people learn sign language with the support of technology, collective awareness of communicative diversity is strengthened and exclusionary gaps are reduced, contributing to the construction of more inclusive societies that respect the linguistic rights of deaf people (UNESCO, 2017). Inclusive schools become spaces where all languages—verbal, written, or gestural—are equally valid and respected, in line with the principles of inclusive education and universal accessibility (Booth and Ainscow, 2011; De Jesús-González et al., 2023).

In summarizing the literature review, it was observed that the theoretical and empirical evidence examined demonstrates that integrating information and communication technologies into the teaching and learning of sign language is a key factor in promoting the educational and social inclusion of people with hearing impairments. The studies analyzed in the Dominican Republic, Ecuador, and Colombia confirm the effectiveness of digital tools—such as mobile apps, interactive platforms, teacher training programs, and audiovisual resources—in strengthening learning autonomy, improving communication, and facilitating content comprehension in various educational contexts (Palomino et al., 2022; Martínez-Acosta et al., 2022; Córdova Guerrero, 2022). Likewise, a common trend is observed toward the use of innovative methodologies based on gamification, interactivity, and constructivist learning, which promote active student participation and foster the creation of more accessible and motivating environments (Deterding et al., 2011; Kapp, 2012). These experiences demonstrate that technology acts not only as a support resource but also as a pedagogical mediator capable of transforming traditional practices and eliminating

historically entrenched communication barriers (García Rivera and Céspedes Guevara, 2025).

All of this means that the reviewed literature supports the relevance of this approach and demonstrates that ICT-mediated learning in sign language not only enhances the linguistic and cognitive skills of deaf learners but also promotes a more equitable and diverse education that is consistent with the principles of inclusion and universal accessibility (UNESCO, 2017; Booth and Ainscow, 2011).

METHODOLOGY

This research used a qualitative, descriptive approach to understand and identify the most appropriate technological tools for learning sign language at the María Doraliza Educational Institution in the District of Riohacha. This approach enabled an analysis of educational reality from an interpretive perspective, taking into account teachers' experiences and the institutional context, rather than relying solely on numerical data. The choice of this methodology responds to the need to explore in depth the available digital resources and their potential impact on inclusive education. The study was based on a systematic literature review, drawing on academic sources, scientific articles, institutional projects, and databases specializing in educational technology and inclusion. This review enabled the collection of relevant information on the use of ICT in teaching sign language, as well as on successful experiences implemented in other educational contexts. The systematization of this information enabled the establishment of a solid theoretical foundation for identifying and evaluating the most relevant technological tools.

To ensure a thorough search, highly relevant databases such as Google Scholar, SciELO, and Redalyc were examined, along with the institutional repositories of national and international universities. Search queries were constructed by combining descriptors and Boolean operators, as illustrated below: "Sign Language" and "ICT"; "Self-Directed Learning" and "Educational Inclusion"; and "Technological Tools" and "Hearing Impairment." The following inclusion criteria were established for selecting the document corpus: (a) thematic

relevance to technology-mediated sign language learning, (b) recency of publications, preferably from the last ten years, and (c) academic quality of the source. The structuring of this data facilitated the formulation of a theoretical framework for selecting appropriate technological tools. In addition to the literature review, exploratory observations and contextual analyses were conducted at the María Doraliza Educational Institution to identify existing technological conditions, students' communication needs, and the pedagogical strategies employed by teachers. These observations were carried out in a participatory manner, prioritizing an understanding of the actual dynamics of interaction between deaf and hearing students. The data obtained were classified according to the criteria of accessibility, interactivity, pedagogical relevance, and usability.

From an ethical standpoint, the document aligns with institutional guidelines and the principles of educational reasoning, ensuring confidentiality and mutual respect. This procedure involved obtaining participants' prior consent before discussions began, a document that generated controversy and was subsequently signed. If participants were minors, parental consent was obtained; parents agreed to collaborate independently and to use the collected information for academic and research purposes, ensuring the confidentiality of the information at all times. The methodological process concluded with the identification and comparative analysis of various technological tools designed for sign language learning, including platforms such as HandSpeak, Incluseñas, and SignaTalk, as well as audiovisual resources and virtual learning environments. Through this methodology, it was possible to determine the educational potential of each tool and highlight those that promote autonomous learning, gestural comprehension, and inclusive participation. Overall, the methodology employed ensured a comprehensive, coherent, and contextually grounded view of the phenomenon under investigation, enabling the study to achieve its central objective.

Despite its rigorous methodological approach, the study is not without limitations that must be taken into account when interpreting the findings. First, due to its qualitative-descriptive nature and its specific scope within the María Doraliza Educational Institution, the findings cannot be generalized to all educational institutions in Colombia, given that technological

infrastructure and teacher training conditions vary significantly across regions. Second, the research was based primarily on document review and exploratory observation, which does not allow for quantifying the long-term impact of the identified tools on students' academic performance. Finally, limited high-speed internet connectivity in the Riohacha region may hinder the use of some of the web platforms and gamification tools investigated.

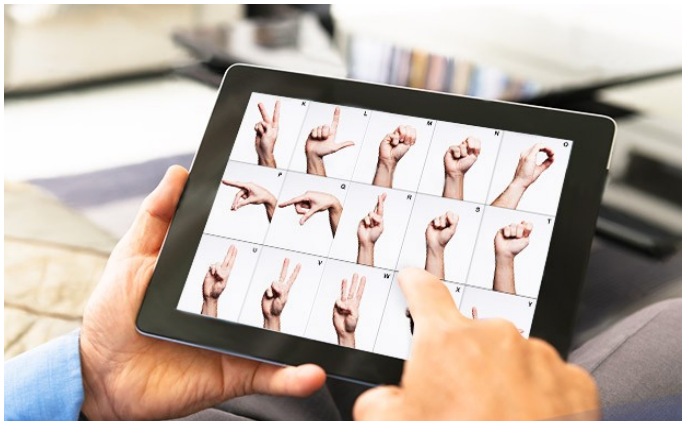
RESULTS

This section presents the main findings of the analysis of the technological tools used for learning LSC at the María Doraliza Educational Institution in the District of Riohacha. The findings are organized around three main themes: 1) the characterization of the technological tools used and their pedagogical relevance, 2) the perceived effects on students' autonomy and communicative performance, and 3) the implications of these experiences for building a more inclusive institutional culture. Based on this framework, the results are described and analyzed, highlighting the opportunities and challenges posed by integrating technologies in inclusive education contexts.

The incorporation of technological tools into the teaching and learning of sign language has led to significant transformations in the educational sphere. With the implementation of digital platforms, audiovisual resources, and virtual learning environments, results are evident, reflecting progress in both student autonomy and the consolidation of a more inclusive institutional culture. These results demonstrate how technological innovation can be an effective means of overcoming communication barriers and promoting equity in settings where inclusion has traditionally lagged.

Figure 1

The Process of Integrating Technology into the Teaching and Learning of Sign Language



Note. Taken from Zárate (2023).

Self-directed learning of a foreign or second language is becoming increasingly accessible thanks to the integration of ICT, which provides students and teachers with tools such as software, multimedia resources, and apps. Similarly, the integration of ICT into educational institutions' learning platforms is becoming increasingly common, an essential element in promoting self-directed learning.

Sign language, on the other hand, is largely unknown among the general population, even among deaf people. LSC instruction in schools has been conducted using an oralist approach and with support from regional sign language variations due to a lack of professional sign language interpreters. Thanks to the Organic Law on Intercultural Education, the social integration of the deaf community must be included in the education system; in this way, the social inclusion and integration of deaf people can be promoted, achieving an education free of communication barriers (De Jesús-González et al., 2023). To overcome these obstacles and promote inclusion, various educational institutions globally are offering LSC courses. Various technologies have been implemented to teach these languages, such as wikis, online rubrics, and project and research platforms. These digital tools are essential for simplifying the learning process and ensuring that education for people who are deaf is truly accessible and efficient. Furthermore, given that the use of ICTs for foreign language learning has increased in some countries, this paper explores the technologies available for sign language learning.

In educational settings where a lack of inclusion limits equitable access to knowledge, technology emerges as a strategic ally for transforming teaching and learning. The integration of digital tools designed for sign language not only promotes communication between deaf and hearing students but also drives pedagogical innovation and raises awareness of diversity. Below, we analyze the main technological tools that strengthen these processes, among which the following stand out:

HandSpeak: is a digital platform that offers visual dictionaries, multimedia resources, and explanatory videos to help users understand signs, idioms, and communicative contexts. In institutions lacking interpreters or inclusive materials, HandSpeak becomes an essential self-learning resource. Its visual and intuitive structure facilitates the incorporation of sign language into formal and informal educational settings, promoting student autonomy and reinforcing intercultural understanding between deaf and hearing individuals.

Incluseñas: is a mobile app that combines interactive practice modules, gesture recognition, and progressive exercises with immediate feedback. In contexts where in-person teaching resources are limited, Incluseñas offers a flexible and accessible alternative. Its gamification-based approach stimulates student motivation and encourages continuous practice, which reinforces meaningful learning of sign language. Additionally, it fosters empathy and encourages the educational community to participate in building an inclusive culture.

SignaTalk: is artificial intelligence-based software that translates text into sign language in real time, facilitating two-way communication between deaf and hearing users. This type of technological innovation enhances communicative accessibility in settings where interaction between teachers and deaf students is often limited. Its ability to translate content in real time makes it a valuable tool for lectures, tutoring sessions, and educational materials. SignaTalk directly contributes to effective inclusion by ensuring that information flows equitably across various educational processes.

Audiovisual resources (educational videos, animations, tutorials, platforms, and multimedia content): these provide a dynamic visual representation of sign language. In settings with hearing impairments or limited access to specialized materials, audiovisual resources are essential for meaningful learning. These materials promote knowledge retention by

combining images, movement, and real-life communicative contexts. Furthermore, they help raise awareness throughout the educational community by showcasing examples of effective communication between deaf and hearing individuals. From a technology management perspective, they constitute a flexible, scalable means of strengthening inclusive, visual teaching.

The set of tools analyzed represents a strategic convergence between technological innovation and social commitment. In educational contexts lacking inclusion, their implementation helps overcome structural and cultural barriers that have historically limited deaf people's participation; these technologies promote the creation of more open, accessible, and empathetic learning environments, where communication becomes a bridge rather than a barrier. From the perspective of technology and innovation management, it is evident that investing in inclusive digital solutions not only improves educational quality but also drives a cultural shift toward equitable, sustainable, and technologically transformative education, taking into account key factors that ensure the desired outcome:

1. Autonomy in learning sign language:

The use of technological tools such as HandSpeak, along with inclusive and diverse audiovisual resources, has fostered greater independence in the learning process. Students develop communication skills in a self-directed manner, exploring visual materials and interactive exercises that strengthen their understanding and practice of sign language without relying exclusively on in-person instruction (Marschark and Spencer, 2010; Palomino et al., 2022). This autonomy contributes to the development of self-learning and knowledge management skills, which are essential in inclusive and digitized educational environments, where ICTs serve as key mediators for accessing information and constructing knowledge (De Jesús-González et al., 2023). Furthermore, asynchronous access to content allows students to progress at their own pace, review lessons as many times as they deem necessary, and reinforce the aspects that pose the greatest difficulty for them. This temporal and spatial flexibility fosters more personalized learning processes, in which the student takes a leading role in constructing their knowledge and regulating their own study strategies,

which is fundamental for strengthening communicative competence in sign language (Zimmerman, 2013).

Similarly, the use of platforms and apps designed specifically for the deaf community enables the creation of learning pathways tailored to each learner's language proficiency, interests, and specific needs. This promotes self-regulation, constant monitoring of one's own performance, and decision-making regarding what content to practice, when, and with what resources—elements associated with deeper and more meaningful learning (Boekaerts and Corno, 2005; Panadero, 2017).

Finally, autonomy in ICT-mediated sign language learning also fosters the development of a stronger communicative identity, as students feel more confident practicing independently, experimenting with new signs, and validating their progress through the visual and multimedia feedback these tools provide. This contributes not only to linguistic proficiency but also to personal empowerment and more active participation in the educational and social contexts in which they operate (Palomino et al. 2022).

2. Motivation and Participation in Inclusive Processes:

The technological platforms analyzed have led to a significant increase in student motivation and active participation in educational settings. The incorporation of interactive activities, immediate feedback, and multimedia content has transformed the perception of sign language learning, shifting it from a traditional process to a meaningful and engaging experience (Deterding et al., 2011; Kapp, 2012). This innovative approach has enabled both deaf and hearing students to engage collaboratively in inclusive communication practices, strengthening peer interaction and recognizing sign language as a legitimate communication resource in the classroom (Palomino et al., 2022; UNESCO, 2017). Similarly, the presence of playful resources, progressive challenges, and activities that integrate real-life situations has strengthened the sense of belonging and interest in learning sign language as a practical communication tool. The opportunity to interact in simulated environments, participate in technology-mediated group activities, and receive recognition for achievements has a positive impact on students' willingness to take on new tasks, share their progress, and contribute to building a more empathetic and inclusive school climate (Ryan and Deci, 2000).

Furthermore, the incorporation of gamification elements—such as symbolic rewards, levels, badges, and constant feedback—fosters intrinsic motivation by making the learning process more challenging, dynamic, and aligned with students' interests, especially in ICT-mediated contexts (Werbach and Hunter, 2012). This helps deaf students feel valued and seen, while hearing students develop attitudes of respect and openness toward communicative diversity. In this regard, the reviewed experiences demonstrate that the combination of accessible technological resources with inclusive pedagogical approaches not only increases participation in academic activities but also strengthens a sense of community, collaborative work, and the joint construction of meaning around sign language. In this way, technology becomes a bridge to promote more horizontal relationships, shared learning environments, and educational practices that recognize and celebrate difference (Booth and Ainscow, 2011).

3. Reducing communication barriers:

The integration of artificial intelligence-based software, such as SignaTalk, and the use of LMS platforms like Moodle have significantly helped reduce communication barriers between teachers, hearing students, and deaf students. These technologies facilitate the translation, comprehension, and dissemination of educational content in real time, ensuring more fluid and equitable communication. This outcome demonstrates the potential of technology to promote universal accessibility in teaching and learning environments.

In practice, this has led to improved classroom interaction, increased participation by deaf students in academic activities, and a greater understanding among faculty of the communication needs of this population. The use of technological mediators to interpret sign language, subtitle content, or supplement oral explanations has enabled information to be conveyed more clearly and in a more timely manner, reducing misunderstandings and fostering more horizontal relationships among the various educational stakeholders.

4. Strengthening an inclusive institutional culture:

The educational use of Information and Communication Technologies (ICT) has driven a positive transformation in institutional culture. Technological tools have not only facilitated

the learning of sign language but have also raised awareness within the educational community about the importance of inclusion and communicative diversity. This cultural strengthening promotes institutions' commitment to equity, innovation, and social sustainability, and consolidates an educational vision centered on inclusion and technology.

The results show that incorporating innovative technologies into sign language learning not only optimizes educational processes but also drives a structural shift toward educational inclusion. Autonomy, motivation, and reduced communication barriers are established as pillars of a modern and equitable education. Furthermore, strengthening an inclusive institutional culture demonstrates that technology, when strategically managed, can be a transformative tool for building more accessible, empathetic, and sustainable educational communities.

Additionally, a table is presented showing the characteristics and findings of the technological tools for sign language:

Table 1

Technology tools for sign language

Tool	Key Features	Findings and contributions to the study
HandSpeak	It is a digital tool that includes visual dictionaries, multimedia resources, and explanatory videos on signs and expressions.	It is recognized as an indispensable self-learning tool that compensates for the lack of interpreters and fosters autonomy and intercultural understanding.
Incluseñas	A mobile app that features interactive modules, gesture recognition, and an immediate feedback system.	Its emphasis on gamification significantly boosts student motivation and ensures consistent, adaptable practice in resource-limited settings.
SignaTalk	SignaTalk is artificial intelligence (AI)-based software designed to translate text into signs in real time.	It promotes effective two-way communication in real time (in class and during tutoring sessions), eliminating the limitations of interaction between hearing educators and deaf students.
Audiovisual Resources	Audiovisual resources include educational videos, animations, tutorials, and interactive multimedia content.	Knowledge retention is enhanced through visual representations of movement and real-world context; furthermore, this approach offers high scalability for inclusive technology management.

Supplementary Digital Tools	Additional digital tools: wikis, digital rubrics, and project and research management platforms.	They function as auxiliary components that facilitate the educational process and ensure that education is accessible and effective in accordance with established quality standards.

Note. Taken from Palomino et al. (2022).

DISCUSSION OF RESULTS

The expected results are consistent with recent research (Palomino et al., 2022; Córdova Guerrero, 2022) that demonstrates the potential of ICT to promote educational inclusion and accessibility. However, technology alone does not guarantee effective learning: it requires teacher support, an adapted curriculum design, and an institutional commitment to diversity. The experience at the María Doraliza Educational Institution shows that when technological tools are integrated pedagogically, both empathy and communication skills are strengthened; therefore, it is essential to establish a training strategy that allows for the sustainable integration of these tools into the classroom.

The results confirm that the use of platforms such as HandSpeak, Incluseñas, and SignaTalk, as well as audiovisual resources and LMS environments (such as Moodle), not only improves the pedagogical experience but also strengthens the institutional framework around inclusion. These tools enable more dynamic interaction among educational stakeholders, reducing communication gaps and fostering collaborative and accessible learning. In this regard, one of the practical contributions of this research is the identification of a set of specific technological tools that can be integrated into instructional sequences for teaching Colombian Sign Language in similar school contexts, offering guidelines applicable to other institutions.

Furthermore, the incorporation of ICT into educational processes helps foster an inclusive institutional culture in which linguistic and communicative diversity is recognized as a strategic value. When applied in a pedagogical and sustainable manner, technology is not merely a teaching resource but becomes an agent of social and educational change. Compared to other studies that address inclusion from a more general perspective, this study offers an approach grounded in the realities of a public institution in Riohacha, highlighting the

specific needs, opportunities, and challenges that arise in implementing technological tools for learning sign language. From a practical perspective, the findings allow the proposal of guidelines for designing teacher-training programs on the use of inclusive digital tools, as well as criteria for selecting and adapting technological resources geared toward LSC learning. Similarly, the study offers insights to help the institution advance in formulating internal policies that explicitly integrate communicative accessibility as a cross-cutting theme in pedagogical projects. This added value distinguishes the present research from other studies by linking the analysis of technological tools to pedagogical decision-making and institutional management.

However, it is important to acknowledge the limitations of this study. The main limitation is the technological infrastructure and connectivity gaps that persist in the District of Riohacha, which prevent the real-time implementation of cloud-based or artificial intelligence tools. Furthermore, the qualitative scope of the research, while rich in interpretation, is insufficient to measure the statistical impact of using these tools on students' long-term academic performance. On the other hand, the rapid evolution of educational software means that some of the applications cited here could become obsolete with new operating systems.

As suggestions for future research, we recommend moving toward experimental or quasi-experimental studies that measure improvements in communication skills following consistent use of these ICTs. It is also recommended to expand the sample to other institutions in the department of La Guajira to verify the scalability of the proposal in bilingual contexts (LSC). Subsequently, it is recommended that local software be developed that integrates idioms and regionalisms specific to the Caribbean LSC.

On the other hand, incorporating sign languages into the design of communication technologies recognizes the right to autonomy and respects Deaf culture. In this regard, as Llamazares de Prado (2021) noted, inclusive technologies help democratize culture and access to information regardless of where one lives in the world, in an increasingly globalized world with more channels of communication. For this very reason, Deaf communities around the world should have access to free or low-cost inclusive technologies.

In recent years, assistive technologies have focused on facilitating communication and interaction among Deaf people. The study of these tools' contributions to society has gone beyond the technical and practical. For example, in their research, Dyzel et al. (2020) reviewed assistive technologies for people with hearing or visual impairments across objectives, design, development, acquisition, implementation, and impact. This highlights researchers' interest in evaluating these technologies from the perspective of their ability to improve the psychological well-being and quality of life of people with special needs and access difficulties. Furthermore, in this research, it is of interest that the selected technologies be accessible to a global community that, in general, faces difficulties accessing such tools due to socioeconomic vulnerability (Alshawabkeh et al., 2021).

In the same vein, Sousa et al. (2019) note that accessibility and usability are essential characteristics of assistive technologies for the deaf. Accessibility is fundamental to understanding information. Among accessible formats are sign language and captions, which affect the usability of this technology. But that is far from the truth.

Furthermore, much research on inclusive technologies has focused on the development of oral communication skills. As a result, many technologies based on cochlear implants and other devices improve hearing and support speech rehabilitation and lip-reading. However, here we wish to highlight assistive technologies for sign language to improve communication for deaf people through digital literacy.

As noted by Flórez Aristizábal et al. (2010), more research and technologies are needed to support the use of sign language and ICT in children's education, as learning processes during childhood are crucial. Such studies and developments should promote the use of digital support tools both inside and outside the classroom to facilitate communication between deaf and hearing individuals. In the same vein, the use of assistive technologies for teaching sign language at various educational levels is relevant and benefits not only students but also teachers and family members. Furthermore, as noted by Hernández et al. (2020), the use of hybrid technology approaches within the design for all framework can integrate access to education and literacy in sign language. Therefore, deaf communities need assistive technologies in sign language that can be used in various settings.

Many technologies focus on deaf students, but there is still a need to adapt workplaces for deaf adults using assistive technologies. As Alshawabkeh et al. (2021) point out, existing tools fail to meet the needs of deaf people in the workplace. Such technologies should also promote the universal use of sign language. This opens the door to future lines of research in the field and addresses the third research question.

One obstacle to conducting research with the deaf community is the diversity of needs it encompasses. In fact, most of the assistive technologies identified in this study are prototypes. Furthermore, it is important to consider financial resources, as developing accessible, sustainable, and applicable technologies involves high costs and requires time. This research addresses general themes in assistive technologies: the incorporation of sign language, accessibility, and improved communication between deaf and hearing individuals. These technologies enable deaf communities to articulate their needs and rights, strengthen their culture, and participate in a new society that does not impose its language.

These findings provide an overview of the technologies currently available to deaf sign language users. They can be useful to private organizations, educational institutions, government agencies, and, in general, any individual or organization working on the development of assistive technologies in sign language. The results also highlight the need to evaluate and adjust government policies and strategies to develop, create, disseminate, and promote these tools. In summary, the discussion of the results demonstrates that leveraging technological tools in contexts lacking in inclusion drives educational transformation toward more participatory, equitable, and technologically advanced settings. At the same time, it reaffirms the need to continue innovating in teacher training and in the design of institutional policies that guarantee a truly accessible education for all, and positions the experience of the María Doraliza Educational Institution as a model that can be replicated and adapted to other educational contexts across the country.

CONCLUSIONS

The incorporation of digital tools such as HandSpeak, Incluseñas, and interactive audiovisual resources has transformed the student's role, giving them greater control over their own learning process. These technologies enable continuous practice, self-directed exploration, and access to visual materials anytime, anywhere, fostering independence and self-assessment. The autonomy gained not only strengthens communicative competence in sign language but also develops self-regulation, knowledge management, and critical thinking skills—essential elements for inclusive and sustainable learning in the digital age.

Furthermore, the use of platforms like Incluseñas and gamification resources has significantly increased student motivation, transforming the educational experience into a dynamic, participatory, and emotionally engaging activity. Immediate feedback, interactive challenges, and the ability to share progress in collaborative environments encourage active participation from both deaf and hearing students. These tools turn sign language learning into a meaningful experience that fosters engagement, empathy, and a positive appreciation of communicative diversity, promoting true inclusion both inside and outside the classroom. It is worth noting that technological innovations, such as SignaTalk, powered by artificial intelligence, and LMS platforms (such as Moodle), have helped break down traditional barriers between deaf students, hearing students, and teachers. Thanks to simultaneous translation, real-time sign display, and accessible materials, educational communication has become more equitable and fluid. These tools ensure that information flows without auditory or linguistic limitations, reaffirming technology's role as a mediator of intercultural dialogue and a promoter of true universal accessibility in academic settings.

These platforms operate within an information technology (IT) ecosystem that combines computer vision for sign recognition, 3D rendering engines for sign visualization, and cloud architectures for multimedia content storage. These tools enable an interaction in which input gesture data is processed in real time to generate an immediate educational response. However, it is important to clarify that, given the descriptive scope of the research, the analysis focuses on evaluating the usability of these technological processes; therefore, neither the technical development of the final product nor the source code of the platforms is

presented, but the technical roadmap for future implementation at the María Doraliza Educational Institution is defined.

In this regard, the implementation of ICT with an inclusive approach has had a profound impact on institutional culture, promoting awareness, respect, and appreciation for communicative diversity. The consistent use of accessible digital resources has fostered more empathetic and collaborative teaching practices, in which sign language is recognized as an essential component of the educational ecosystem. This cultural shift reinforces the institutions' commitment to equity, innovation, and social responsibility, and consolidates an educational vision that integrates technology, inclusion, and human development as pillars of sustainable transformation.

How to cite: Meriño Mejía, M. M., and Madrid Orrego, D. M. (2026). Management of Technological Tools For Learning Sign Language. *Journal of the Academy,* (14), 232-261. https://doi.org/10.47058/joa14.12

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