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PAPER

Interactive Mobile Applications for Social Communication in Deaf and Hearing-Impaired Populations: A Systematic Review

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ABSTRACT

Mobile applications have become an important tool in reducing communication barriers for individuals with hearing impairments. While sign language enables communication within the deaf community, challenges remain when interacting with hearing individuals who do not understand sign language. This study aims to identify types of mobile applications developed for this purpose, analyze how their features support communication skills, and evaluate their impact on social interaction. Using a systematic literature review (SLR) with the PRISMA approach, 21 articles indexed in Scopus and DOAJ were analyzed. The findings reveal diverse applications, including AI-based sign language translators, interpreter-assisted communication tools, deaf-friendly social media, gesture recognition, 3D sign language animation, and real-time speech-to-text. Key features such as real-time translation, interactive tutorials, and 3D animations enhance sign language learning, promote independence, and increase social participation. Mobile applications demonstrate significant positive impacts on accessibility, education, healthcare, and daily interactions, while fostering inclusion and empowerment for deaf individuals. This study also introduces the inclusive mobile communication framework, which integrates technological affordances with the mobile learning principles, universal design for learning, and the social model of disability.

KEYWORDS

mobile applications, deaf, hearing impairment, social communication, inclusive technology, systematic literature review (SLR)

1 INTRODUCTION

Deaf individuals often face significant challenges in social communication, especially when interacting with people who do not understand sign language. These barriers limit their access to various aspects of life, including education, employment, and public services [1]. One such challenge is the difficulty in accessing healthcare

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services due to the lack of medical personnel with sign language proficiency [2]. In Brazil, the shortage of medical personnel who can communicate in sign language has led to communication barriers in healthcare services [3].

Attitudes toward sign language vary across countries. In Kenya, sign language serves as the primary medium of instruction for deaf students from early education through university to support academic achievement and social interaction [4]. However, the situation is different in Canada, where the closure of special schools for deaf children has disrupted sign language instruction and the social identity of deaf children [5].

In daily life, limitations in understanding verbal communication often lead to feelings of frustration and isolation for deaf individuals, especially in environments dominated by hearing people [6]. Monolingual ideology and audism in countries like Spain further exacerbate the situation, as they prioritize spoken language over sign language [7]. This underscores the importance of solutions that bridge the communication gap between deaf individuals and the general public.

With technological advancements, various communication aids have been developed, ranging from hearing aids and sign language interpreters to automatic transcription systems. In education, the lack of sign language or text-based communication facilities also hinders deaf students' learning, impacting their academic performance and engagement [8].

As an alternative solution, the use of mobile applications has begun to gain attention in supporting social communication for the deaf. Several text-based applications, sign language recognition, and augmented reality have shown potential in improving social interaction [8]. For example, the *Social + Me* app helps deaf students in Chile build social connections to reduce isolation [9], while other apps facilitate communication for volunteers in emergency situations [10].

Some studies have also developed applications aimed at improving the social communication skills of deaf individuals. Another study designed the mobile-based *AsEar* application to enhance sound awareness among the deaf [11]. Applications such as *Be a Buddy* and *Accessibility Redefined* assist deaf individuals in communicating with people who do not understand sign language by translating it into text or speech, thereby reducing linguistic isolation and supporting social inclusion [12]; [13]. However, previous research remains limited in examining the role of mobile applications in enhancing social communication for the deaf within workplace or public service environments.

Although these applications have great potential to enhance accessibility for the deaf, most studies have focused on technical aspects and system development rather than exploring their impact on real-world social communication. Most studies have centered on technological development, such as artificial intelligence (AI)-based sign language recognition or speechreading training, without testing their use in daily life [14]. Additionally, the involvement of deaf individuals in the app development process remains rare [15].

Recent developments in educational technology highlight the growing role of digital and cloud-based innovation in supporting inclusive and transformative learning experiences. Emerging research underscores how cloud technologies, mobile platforms, and AI-enhanced ICT tools can expand access, personalization, and adaptability for diverse learners, including those with communication challenges. For instance, Papadakis et al. emphasize how digital and cloud innovations can reshape learning environments by enabling more flexible, resource-rich, and learner-centered experiences [16]. Similarly, Papadakis et al. illustrate how AI-enhanced ICT can advance lifelong learning through personalized, adaptive, and context-aware systems that respond to individual learner needs [17]. These advancements reinforce the potential of interactive mobile applications to support social communication, particularly for deaf and hearing-impaired populations who rely heavily on accessible, multimodal, and user-centered digital tools.

Based on the above description, this study aims to identify the types of mobile applications that support the social communication of deaf individuals, evaluate the main features used, and examine the impact of their use on social engagement. Through this literature review, it is hoped that this study will provide insights into the development of more inclusive communication technology.

2 RESEARCH QUESTIONS

Based on the issues outlined above, this literature review seeks to answer the following questions:

1. What types of mobile applications have been developed to support the social communication of deaf and individuals with hearing impairment?
2. How do features within these mobile applications contribute to enhancing their social communication skills?
3. What are the real-world impacts of using mobile applications on the social interaction quality of deaf and individuals with hearing impairment?

3 MATERIALS AND METHODS

This study uses the systematic literature review (SLR) method, which has been widely adopted in previous scientific studies. The initial review covered more than 145 articles indexed in Scopus and DOAJ, published between 2019 and 2025. Journal articles were the main source of data in this study, with the limitation of only English-language articles.

The focus of the research is on interactive mobile technology, in line with the researcher's academic expertise. The article search was conducted using a combination of keywords such as "mobile applications," "deaf" or "hearing impairments," and "communication" that are relevant to the use of mobile applications in improving communication for deaf individuals.

The study filtering process in this systematic review follows a PRISMA flowchart to ensure the inclusion of the most relevant articles. This process is divided into four main stages: Identification, Screening, Eligibility, and Included (see Figure 1).

1. Identification: The initial identification stage was conducted through a comprehensive search of various leading scientific databases. Focusing on publications between 2019 and 2025, the initial search yielded 113 articles from Scopus and 32 articles from DOAJ. A total of 145 articles were identified from both databases to be processed to the next stage.
2. Screening: The 145 identified articles were then processed for initial screening. At this stage, studies were screened based on publication type, language, and accessibility. A total of 80 articles were excluded because they fell into the following categories: Conference Paper, Paper, Book Chapter, Conference Review, Editorial, Note, Data Paper, not in English, or not open access. After this initial screening, the remaining 62 articles were forwarded for a more in-depth eligibility assessment.

3. Eligibility: At the eligibility stage, the 62 articles that passed the initial screening were examined to determine whether they met the established inclusion criteria. A total of 39 articles were excluded from this review because they were not relevant to the defined research keywords.
4. Included: After going through the entire filtering process, 21 articles ultimately met all included criteria and were included in this systematic review for further analysis.

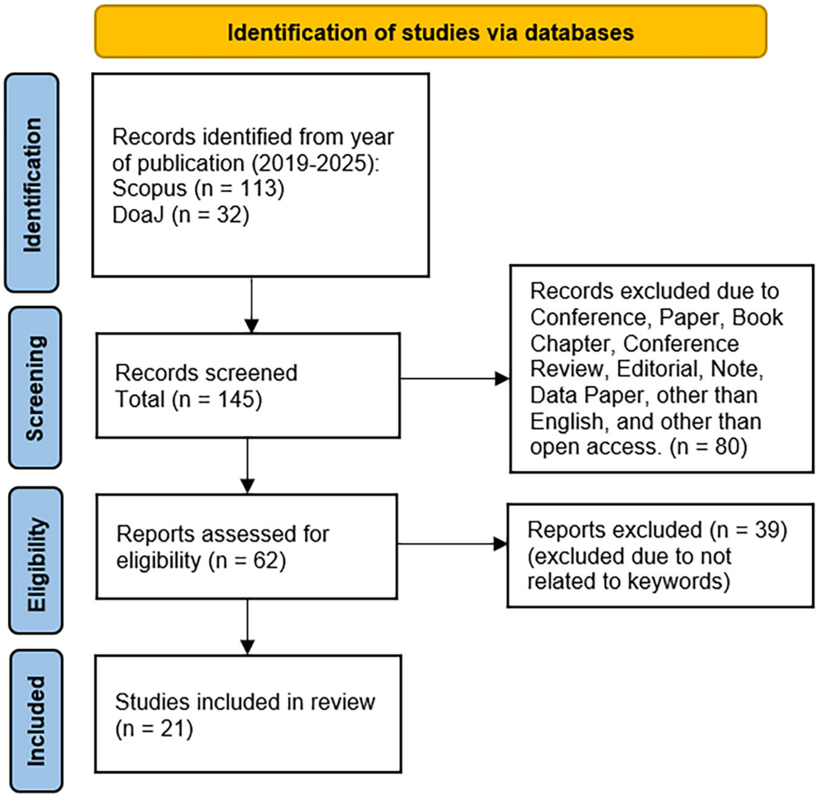

Fig. 1. PRISMA flow diagram

Thus, this systematic study selection process ensures that only the most relevant articles are included in this review. The selected studies will form the basis for analysis to answer the research questions (RQ) that have been established, providing a strong and reliable foundation for the findings and conclusions of this systematic review.

4 RESULTS

This study was conducted to examine the role of technology, particularly mobile applications, as a communication medium for deaf individuals. The study began by identifying the types of applications that have been implemented to assist deaf individuals, followed by an analysis of the improvement in communication skills and the impact of mobile application use on the social interactions of deaf individuals. From the analysis, 21 articles were selected that met the research criteria. The distribution of these articles based on publication year and journal quartile is presented in Tables 1 and 2.

Table 1. Distribution of articles based on year of publication

Year of Publication	Total Articles
2020	2
2021	3
2022	4
2023	6
2024	5
2025	1
Total	**21**

Table 2. Distribution of articles based on journal quartiles

Journal Quartiles	Total Articles
Q1	7
Q2	5
Q3	5
Q4	4
Total	**21**

4.1 Types of mobile applications developed to support social communication for deaf individuals and those with hearing impairments

In this study, 16 articles identified the types of mobile applications that have been developed to facilitate social communication for individuals with hearing impairments. These applications take different approaches, ranging from sign language translation to hand gesture recognition to integration into social media. Table 3 shows a breakdown of the various types of applications commonly used to bridge communication between individuals with hearing impairments and those who cannot use sign language.

Table 3. Types of mobile applications

No	Types of Applications	Results
1	AI-Based Sign Language Translator	AI-based applications have been widely developed to translate sign language into text and speech in real time, helping bridge communication between deaf individuals and the general public. For example, Efhamni uses deep learning to translate Saudi Sign Language into Arabic text and audio, and is used by 100 deaf users [18], while Sign4all applies the ResNet50 model to recognize sign alphabets from RGB images with 79.96% accuracy at low cost [19]. Many apps integrate AI and machine learning to detect and translate sign gestures, offering features such as text-to-speech, speech recognition, and bidirectional translation [12]. These systems often use CNNs, deep learning, and other algorithms to interpret hand movements, facial expressions, and body posture [20].
2	Communication App Based on Translator	Several applications have been studied, including the *Deaf in Touch Everywhere (DITE)*™ application, which was developed as a translator-based communication tool to support deaf individuals in interacting with Malaysian Sign Language (Bahasa Isyarat Malaysia) interpreters, particularly within healthcare contexts [21]. The application features a user-friendly visual interface designed to enhance accessibility and comfort, and was evaluated by nine deaf users and nine interpreters. Translation functionality is among its most common features, enabling users to convert sign language into spoken or written language, and vice versa [20]. Furthermore, other studies have also highlighted that this translation technology plays a crucial role in bridging communication gaps in daily life, while underscoring its significance in modern communication innovations for the deaf community [22].

(Continued)

Table 3. Types of mobile applications *(Continued)*

No	Types of Applications	Results
3	Social Media App Based on Sign Language	Based on findings from other studies, the *Connect Deaf* app developed through the ASM4Deaf project, is a social media platform that enables deaf users to interact using sign language across various platforms like WhatsApp, Messenger, Telegram, and Viber [23]. The application features a sign language keyboard, animated videos/GIFs, text-to-speech and speech-to-text conversion, as well as a context dictionary. Supporting 17 sign languages, the app was rated as easy to use by 80% of participants, with 60% indicating they were likely to use it.
4	Gesture Recognition Application	Hand gesture recognition applications are widely utilized to facilitate communication for individuals who are deaf or hard of hearing. One study developed a sign language application using the SCRUM method to enhance flexibility and user comprehension [24]. For example, a study created a dataset for Pakistani Sign Language (PSL) to recognize the Urdu alphabet based on specific hand configurations [25]. Another research project designed a real-time system for Mexican Sign Language (Lengua de Señas Mexicana), achieving an accuracy rate of 99% [26]. Additionally, Malaysian Sign Language (Bahasa Isyarat Malaysia), an Android application for Malaysian Sign Language was successfully developed using the SSD-MobileNet-V2 FPNLite model, achieving 99.75% accuracy for letters and 61.60% for word gestures, thereby demonstrating significant potential in supporting direct two-way communication [27]. This technology typically relies on *computer vision* methods such as skeleton tracking and motion detection to ensure accurate gesture recognition [20]. Other studies have also emphasized that gesture recognition systems capable of translating sign language into speech, and vice versa, play a crucial role in bridging communication gaps between deaf individuals and their surrounding environments [22].
5	Text-to-3D Sign Language Animation	Another type of communication application designed for the deaf is a text-to-3D hand gesture animation translator. One study developed the SIBI Text-to-3D Animation Translation app, which converts text into 3D animations of Indonesian Sign Language using motion capture technology and Dirichlet Free-Form Deformation (DFFD) to achieve natural hand and mouth synchronization [28]. With high translation speed (<100 ms) and good usability, the application supports improved communication accessibility for the deaf.
6	Text-to-Sign Language App	The Sign4PSL application translates text into PSL in real time and is available on web and mobile platforms, even offline [29]. It uses a PSL word database with sign notations to support communication and sign language learning in special schools. This text-to-sign feature is also implemented in other applications, with findings showing that converting text into sign animations helps users understand and convey messages visually and interactively [20].
7	Speech-to-Text App	The Deaf Chat application converts speech to text in real time, enabling deaf users to follow conversations with greater ease [30]. With multiple speaker recognition, it improves transcription accuracy by detecting multiple speakers simultaneously, supporting interaction between deaf and hearing individuals. Similar apps also employ real-time speech recognition or speech-to-text to display spoken language as text, enhancing communication inclusivity [20]. The automatic captioning feature is also recognized as a key tool in empowering communication for the deaf [22].
8	Sign Language Translation App for Education	Alobaidy and Ebraheem developed an application that translates Iraqi Sign Language into Arabic text and vice versa, facilitating both communication and learning. The application is capable of alphabetically translating unfamiliar words and demonstrated positive outcomes in terms of usability and social interaction among 192 deaf students [31]. The significance of digital tools in sign language learning is further emphasized by other researchers, who assert that sign language education for deaf children should be strengthened through the use of interactive digital resources [22]. Additional studies also highlight that such applications are designed to support not only deaf users but also beginners in learning sign language [20].
9	Sound Awareness App	A mobile application called *AsEar* App has been developed specifically to help deaf and hard-of-hearing (DHH) individuals become aware of sounds in their environment. This application functions as an assistive device to detect and identify various important everyday sounds, such as doorbells or dog barks, which are then communicated to the user through visual notifications and vibration patterns [11].

A review of nine categories of mobile applications shows that technology supporting communication for individuals with hearing impairments is highly diverse and innovative. Solutions range from AI, gesture recognition, and speech-to-text, to 3D sign language animation and sign language–based social media. These tools emphasize two-way translation between sign language and text or speech via visual recognition, text input, or speech technology. Most achieve strong user satisfaction, especially in education, healthcare, and daily interactions, bridging communication gaps and empowering deaf individuals in digital life.

4.2 Contribution of application features to social communication skills of deaf and individuals with hearing impairments

A review of several studies shows that mobile applications for individuals with hearing impairments incorporate features that enhance social communication through interactive, visual, and real-time two-way communication capabilities. Table 4 summarizes these features and their contributions.

Table 4. Features in mobile application

No	Features in Applications	Results
1	Real-time Sign Language to Text and Voice Translation	The automatic translation feature of Saudi Sign Language (SSL) into Arabic text and audio within the *Efhamni* application significantly assists deaf users in conveying messages to others. This enables faster and clearer two-way communication with family, friends, audiologists, and teachers, thereby expanding the scope of social communication in various situations [18]. Furthermore, the sign language to text or voice translation feature significantly enhances inclusivity, fosters understanding across diverse communities, and bridges communication barriers through various modes of language expression and comprehension [12].
2	Virtual Sign Language Presenter Characters/ Virtual Sign Language Avatars	In an educational context, the *Sign4PSL* application features virtual characters that visually demonstrate PSL in animated form. This feature has proven to make it easier for deaf students to understand signs better, while also enabling independent learning through an offline translation feature. This provides opportunities for students to consistently practice their communication skills outside the classroom [29].
3	3D Hand Gesture Animation	The 3D animation feature in the SIBI Text-to-3D Animation application can convert text into 3D animations of Indonesian Sign Language. This realistic visualization of hand movements helps users understand signs more accurately, thereby increasing participation in learning and daily social interactions [28].
4	Interactive Video Tutorials	Applications like Malaysian Sign Language (Bahasa Isyarat Malaysia) utilize interactive videos to enhance sign language learning, proven more effective than static media. Many users suggested adding a built-in dictionary for daily communication support [32]. Other apps such as *Efhamni* application, feature real-time video recognition, chat, and translation of SSL into Arabic text and audio [18].
5	Real-time Speech-to-Text and Text-to-Speech	By converting speech into live text, this feature enables deaf individuals to follow conversations in real-time, thereby streamlining communication in social situations [30].
6	Human-Mediated Sound Detection & Visual/Vibrational Notifications	Applications like the *AsEar* App feature sound detection that enables the identification of environmental noises such as doorbells or knocks. Its primary contribution is providing crucial auditory awareness for deaf and hard-of-hearing (DHH) individuals, often with the mediation of hearing individuals to identify more complex sound contexts. Additionally, the use of easily recognizable vibration patterns and visual notifications ensures that sound information is conveyed effectively and according to user sensory preferences, thereby facilitating environmental understanding and safer interactions [11].
7	Emotional Interface Personalization	Communication applications for deaf individuals have been developed not only to support basic communication, but also to address the social and emotional needs of their users [33]. The intuitive interface design and interactive features were developed with the participation of deaf users and field experts. The study results indicate that an interface that prioritizes emotional closeness, comfort, and the overall user experience can enhance the quality of social interaction, self-confidence, and emotional support among users [33].

Based on findings from various studies, seven key features in mobile applications significantly support social communication for individuals with hearing impairments: real-time sign language to text and voice translation that accelerates two-way communication and broadens interaction; virtual characters, 3D animations, and interactive video tutorials that facilitate independent, engaging, and easy-to-understand sign language learning; speech-to-text and text-to-speech technologies that enable real-time conversation participation; sound detection with visual and vibration alerts to enhance environmental awareness; and emotionally considerate interface designs that promote comfort, confidence, and improved social interaction quality. Together, these features not only ensure equal access to communication but also create user-centered digital tools that are more inclusive and responsive to the needs of the deaf community, making the development of adaptive, user-focused applications essential for fostering better social inclusion.

4.3 Impact of mobile application use on social communication for deaf and individuals with hearing-impairment

The impact of mobile application use in assisting the social communication of deaf individuals in daily life is quite significant. Various studies indicate that these applications not only aid in basic communication but also enhance independence, accessibility, and social participation. Technology specifically designed to support the communication needs of deaf individuals has opened more opportunities for them to interact in various life contexts, whether personal, social, or professional. Table 5 shows some of the main impacts that have been identified.

Table 5. Impacts of mobile application on social communication

No	Impact	Description & Source
1	Enhancing Social Interaction	The SHAA (Smartphone-Based Hearing Aid App) aids daily communication for users with mild to moderate hearing loss through sound amplification, though it remains less effective than traditional hearing aids [34]. The use of applications such as the *AsEar* App improve social interaction by supporting communication via social media and enhancing users' writing skills [11]. Usability and user-friendly interfaces are key to sustaining engagement and improving better communication [20]. Previous research also emphasizes that sign language-based assistive technologies enhance participation within the deaf community [22].
2	Reducing Communication Barriers	Smartphone-based communication apps play a vital role in bridging the gap between deaf and hearing individuals, especially in healthcare, where many deaf patients struggle to understand medical information [35]. The use of mobile applications also offers various ways to express and understand language, ultimately reducing communication barriers and enabling more active participation [12]. Translation accuracy and speed are key to minimizing misunderstandings [20], while the apps also help overcome linguistic barriers caused by limited public understanding of sign language. Previous research also emphasize that inclusive communication technology can transform linguistic dominance into a form of respect for deaf culture, while integrating it into broader educational, professional, and social contexts [22].
3	Supporting Social Inclusion	The use of mobile applications such as Connect Deaf, which supports 17 sign languages, expands access for deaf individuals to communicate actively on social media. Features such as sign language keyboards, GIFs, Text-to-Speech, and contextual dictionaries enhance user confidence, even in emergencies [23]. Personalized interface designs, as evidenced by previous research, improve inclusivity by addressing emotional needs and user engagement [33]. In line with this, other studies highlight that assistive technologies help create a more equitable social environment by reducing the dominance of majority norms [22].

(Continued)

Table 5. Impacts of mobile application on social communication *(Continued)*

No	Impact	Description & Source
4	Supporting Sign Language Learning	Several mobile applications such as Sign4PSL offer real-time text-to-Sign Language translation with virtual character visualization, which assists deaf students in educational contexts [29]. Meanwhile, the SIBI Text-to-3D Animation application converts text to 3D animations of Indonesian Sign Language, enhancing more accurate movement comprehension and engagement in learning [28]. The Malaysian Sign Language (Bahasa Isyarat Malaysia) learning application also utilizes interactive video tutorials as a learning medium, which has proven more effective than static media such as images or books [32]. In general, features such as visual feedback, animation, and interactive elements in sign language learning applications have been proven to improve student learning outcomes [20]. Furthermore, other studies emphasize the importance of digital technology support in strengthening the early learning process of sign language for deaf children to make it more inclusive and sustainable [22].
5	Enhancing Independence and Accessibility	Mobile applications significantly enhance the independence and accessibility of deaf individuals. Tools such as Deaf Chat enable direct interaction with hearing people [30], while apps such as Petralex provide affordable hearing aid alternatives with features like amplification and noise reduction [34]. The AsEar app helps users respond to environmental sounds [11], and Social + Me supports deaf students in building social connections to reduce isolation [9]. These tools bridge communication gaps, enhance quality of life, and are more affordable than traditional aids [12] [20]. Previous studies emphasize the importance of inclusive technology strategies, including workplace adaptations for the deaf community [22].

Based on the review of several literature sources, the use of mobile applications has a significant and positive impact on the quality of social interaction for individuals with hearing impairments by increasing their active involvement in daily social life and effectively bridging communication gaps, especially in medical contexts, thereby enhancing healthcare service quality. These applications also expand access to social media, promoting a more inclusive and equitable social environment, while their interactive features support sign language comprehension and learning, enriching communication in both social and academic settings and improving the written and visual communication skills of deaf students. Overall, mobile applications play a crucial role in empowering individuals with hearing impairments to achieve more meaningful and higher-quality social interactions.

5 DISCUSSION

This SLR highlights the important role of mobile applications in facilitating social communication for individuals with deafness and hearing impairments. Findings from RQ1 indicate the existence of various types of applications that have been developed, ranging from AI-based sign language translators (e.g., *Efhamni* and *Sign4All*), communication applications with translator assistance (e.g., *DITE™*), sign language-based social media apps (*Connect Deaf*), hand gesture recognition, 3D animation for text-to-sign (*SIBI Text-to-3D Animation*), speech-to-text (Deaf Chat), and learning and voice awareness apps (*AsEar App*). This diversity reflects extensive efforts to leverage innovative technology to overcome communication barriers.

The results of RQ2 specifically expand on these findings by mapping the key features in these applications that have been proven to enhance two-way visual and interactive communication capabilities. The most dominant features include real-time translation from sign language to text and speech, virtual sign language demonstrator characters, 3D animation, interactive tutorial videos, speech-to-text, and an interface supporting emotional personalization. Through RQ3, it was confirmed that these features contribute to improved social interaction, increased independence, and greater access to education and daily communication for deaf individuals.

Technological advancements have created new opportunities for communication within the deaf community. These apps go beyond functionality by fostering user empowerment and deeper inclusion through real-time, accurate, and visual interaction. Such innovation supports not just communication, but also boosts user confidence and social participation in various aspects of life. This analysis is in line with the Affordance Theory, which explains that the environment provides possibilities for action (affordances) depending on individual abilities [36]. Mobile applications with features such as sign language translation to text or voice, 3D animation, and speech-to-text offer easier and more natural communication 'affordances' for deaf individuals in the digital environment, thereby facilitating richer and more meaningful social interactions. This alignment is also evident in the social model of disability, which argues that disability does not lie within the individual themselves, but rather in the barriers created by society and the environment [37]. In this context, these mobile applications can break down these communication barriers while embodying the principles of inclusion and equality that are the goals of this social model.

The findings of this study also expand our understanding of the role of technology in the real lives of deaf individuals, particularly in filling the gaps left by previous research. Previous research tended to focus on system development rather than exploring real-world social impacts [14] and did not involve deaf individuals in the application development process [15]. The results of this study, however, show that existing applications have had a transformative social impact. This indicates that application development should focus on users' real needs, consider effectiveness in everyday life scenarios, and prioritize social inclusion.

The principles of mobile learning and universal design for learning (UDL) are closely aligned with the findings of this study. Mobile learning emphasizes flexible and contextual learning that is accessible anytime and anywhere through mobile devices [38]. The reviewed applications offer tools for learning sign language and facilitating social communication, which deaf individuals can use independently across various settings such as at home, in school, or in public. Features such as interactive video tutorials, 3D animations, and real-time speech-to-text reflect the practical implementation of this approach. Meanwhile, UDL principles that promote diverse forms of representation, expression, and engagement [39] are embodied in features such as sign language translation, virtual characters, and customizable interfaces that support multimodal representation. These applications thus function not only as communication aids but also as inclusive educational tools that cater to users with diverse communication needs.

The findings of this review reinforce how mobile applications operationalize the principles of mobile learning, UDL, and the social model of disability in practice. Mobile learning emphasizes flexibility, accessibility, and contextual learning, which are embodied in features such as real-time speech-to-text, 3D sign animations, and interactive tutorials that allow deaf individuals to learn and communicate in diverse settings. UDL is evident in the multimodal representation of information—sign language, text, speech, and visual notifications—that ensures communication is accessible to a wide range of users. Likewise, the social model of disability highlights that barriers arise not from the individual but from social structures; mobile applications directly dismantle these barriers by creating inclusive digital spaces where deaf and hearing individuals can interact equitably. Together, these theories provide a robust lens to interpret the transformative potential of mobile applications for social participation and lifelong learning.

The findings also extend the scope of mobile learning theory by illustrating how mobile technologies can function not only as tools for flexible, situated learning but also as platforms for social inclusion and multimodal communication. Traditional mobile learning research often emphasizes learner autonomy and context-aware learning experiences; however, the studies reviewed here demonstrate that for deaf and hearing-impaired users, mobile learning entails accessibility-driven personalization, where learning and communication are deeply intertwined. This intersection broadens the concept of mobile learning from an individual cognitive process to a socio-communicative experience that fosters equity and participation.

Similarly, the review reinforces and operationalizes key principles of the UDL framework—namely, providing multiple means of representation, expression, and engagement [39]. The analyzed applications exemplify these principles through multimodal features such as sign language visualization, text and speech integration, and adaptive user interfaces that accommodate diverse sensory needs. By doing so, they translate UDL from an instructional design philosophy into practical affordances embedded within mobile environments.

At the policy level, the study's implications align not only with the UN Convention on the Rights of Persons with Disabilities (UNCRPD) but also with UNESCO's Guidelines for Inclusion and Equity in Education [40]. These frameworks collectively emphasize the need to embed accessibility, adaptability, and inclusive pedagogy into all forms of educational technology. The insights from this review, therefore, contribute to ongoing global dialogues on how mobile learning ecosystems can support inclusive education by integrating accessibility design, policy frameworks, and pedagogical intent.

By connecting the empirical evidence to these broader theoretical and policy discourses, this study positions inclusive mobile applications as a bridge between mobile learning research and disability-inclusive policy practice. This linkage highlights the dual function of mobile technologies—as enablers of flexible, learner-centered engagement and as instruments for achieving educational and social justice.

Drawing on the synthesis of findings, this review introduces the inclusive mobile communication framework (IMCF) as a conceptual starting point rather than a finalized model (see Figure 2). The IMCF serves as an integrative framework that maps the relationships between technological inputs (e.g., AI, gesture recognition, animation, and speech-to-text or sound technologies), interaction mechanisms (mobile learning, UDL, and the social model of disability principles), and user outcomes (enhanced communication, independence and accessibility, and social inclusion). At this stage, the framework functions primarily as a theoretical lens to synthesize evidence and guide future empirical work. It emphasizes a cyclical process where feedback from deaf users can inform iterative refinement, ensuring cultural adaptability and alignment with inclusive policy goals. By integrating multiple theoretical perspectives, the IMCF provides a foundation for future validation and operationalization, offering a holistic yet preliminary conceptual structure for designing and evaluating mobile applications that aspire to be both technologically advanced and socially transformative.

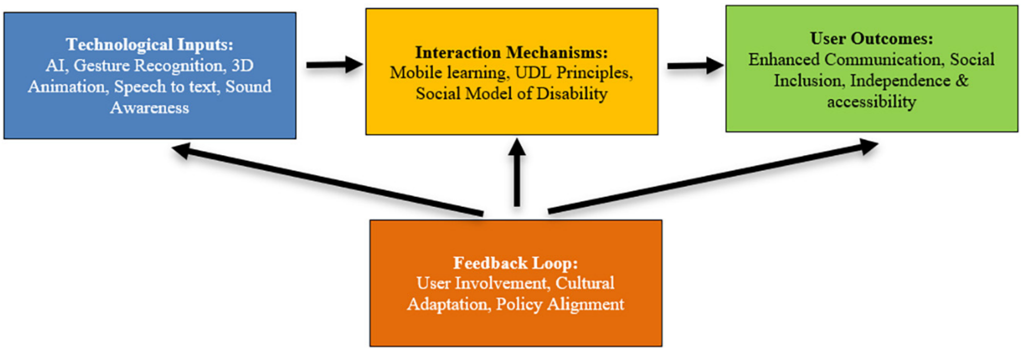

Fig. 2. Inclusive mobile communication framework (IMCF)

5.1 Global transferability and policy implications

While the reviewed studies demonstrate global progress in developing inclusive communication technologies, the transferability of these innovations to low-resource contexts remains uncertain. Many of the reviewed applications were developed in technologically advanced regions with stable internet connectivity, adequate infrastructure, and higher digital literacy levels. In contrast, low- and middle-income countries often face barriers such as limited access to smartphones, high data costs, and insufficient institutional support for digital inclusion. These constraints may reduce the practical reach and sustainability of mobile communication tools, highlighting the need for context-sensitive adaptations that consider infrastructural and socioeconomic disparities.

Another important consideration involves cross-cultural adaptation challenges. Sign languages differ not only across countries but also within communities, reflecting distinct cultural identities and communication norms. Applications developed using one linguistic or cultural framework may not easily transfer to other settings without careful localization. This includes adapting gesture recognition datasets, avatar design, and interface language to align with local sign systems and cultural values. Moreover, the inclusion of deaf users as co-designers is essential to ensure that the technology resonates with community-specific practices and avoids cultural misrepresentation.

From a policy perspective, large-scale implementation of inclusive mobile communication technologies requires multi-level coordination among stakeholders. Governments should integrate mobile accessibility solutions into national disability and digital inclusion strategies, ensuring that they are supported through funding, infrastructure, and teacher or interpreter training. Partnerships between academia, industry, and advocacy organizations can foster co-development and open-source innovation tailored to local needs. International frameworks such as the UNCRPD and SDG 10 [41], and also UNESCO's *Guidelines for Inclusion and Equity in Education* [40] can serve as guiding principles, but they must be operationalized through localized policies that bridge the gap between global commitments and community realities. Ultimately, the success of inclusive mobile communication depends not only on technological advancement but also on equitable access, participatory design, and sustained policy support.

5.2 Research gap and limitations

The findings of this study are highly relevant to global disability inclusion policies. However, a key research gap remains in the integration of UDL principles, which emphasize flexible representation, expression, and engagement. Most reviewed applications have yet to adopt UDL systematically, particularly in non-formal educational contexts.

Cross-cultural issues, such as sign language variations and limited availability of applications tailored to local languages and cultural contexts, continue to hinder equitable access to assistive technology [22]. In developing countries, limited access to devices, internet connectivity, and digital literacy further exacerbate the digital divide, risking the exclusion of people with disabilities from the benefits of technology. Therefore, it is crucial for app developers and policymakers to adopt a context-based and collaborative approach in developing truly inclusive solutions.

Although these limitations are common in systematic reviews, they may have shaped the overall findings of this study. First, publication bias may have resulted in an overrepresentation of studies reporting positive or successful implementations of mobile communication tools, while unsuccessful or unpublished projects remain underreported. This could lead to an overly optimistic picture of the actual effectiveness of such applications.

Second, the exclusion of non-English literature may have limited the global scope of the findings, particularly excluding insights from regions where local sign language technologies are actively developed but not widely disseminated in English-language journals. As a result, the review might underrepresent culturally specific innovations from non-Western contexts.

Third, the absence of a quantitative meta-analysis—due to the diversity of research designs and outcomes—means that this study focuses on descriptive synthesis rather than statistical generalization. Consequently, while thematic and conceptual trends are well captured, the precise magnitude of each intervention's effect cannot be quantitatively assessed.

Furthermore, heterogeneity across the reviewed studies represents both a strength and a challenge for interpretation. The studies varied widely in terms of context (education, healthcare, social media, and daily communication), technological design (AI-based translation, gesture recognition, text-to-sign animation, speech-to-text systems), and evaluation outcomes (usability, accessibility, social participation, or emotional engagement). While this diversity highlights the richness and interdisciplinarity of the field, it also limits the comparability of findings. The variation in sample sizes, user demographics, and cultural contexts complicates the ability to draw uniform conclusions about overall effectiveness. Future research could address this heterogeneity through comparative or meta-analytic approaches that systematically quantify cross-context patterns.

6 CONCLUSION

Based on an SLR of 21 articles, it can be concluded that the use of mobile applications contributes significantly to improving the communication and social interaction skills of individuals with hearing impairments. These applications cover various main categories, such as AI-based sign language translation, communication applications with interpreter assistance, deaf-friendly social media, hand gesture recognition, 3D sign language animation, real-time communication features (text-to-sign and speech-to-text), and sign language translation applications for learning. Although each type of application has different approaches and features, all aim to bridge the communication gap between deaf individuals and the general public. The technologies used are diverse, ranging from deep learning, motion capture to real-time machine learning with high accuracy and usability.

The study also showed that mobile applications not only support two-way communication, but also expand access for deaf individuals to education, health services, and everyday social interactions. User-centered design, along with the integration of key features such as speech-to-text, contextual dictionaries, and real-time translation, has proven effective in promoting their independence and active participation in social life. Therefore, the use of mobile applications as communication aids for the deaf is a potential solution worthy of further development, particularly when considering aspects of inclusivity, accessibility, and adaptation to users' needs in various life contexts.

In addition to these findings, this study introduces the IMCF as a conceptual foundation that integrates technological affordances, mobile learning principles, UDL, and the social model of disability. Rather than a finalized or empirically tested model, the IMCF serves as a theoretical synthesis that organizes key constructs and relationships identified through this review. It provides an initial lens for understanding how mobile applications can potentially enhance accessibility, independence, and social inclusion. Future research should empirically test, refine, and expand this conceptual framework across diverse cultural and technological contexts to establish its validity and practical relevance as a guide for the design and evaluation of inclusive mobile communication technologies.

7 FUTURE WORKS

Future research should prioritize longitudinal evaluations to assess how mobile applications impact users' social communication, independence, and quality of life over time. User-centered design must be systematically integrated, with deaf participants actively engaged as co-creators in the design, development, and evaluation process rather than being passive end-users. Additionally, cross-cultural adaptation of applications is crucial, as sign languages and cultural contexts vary significantly across regions. Comparative studies between developed and developing countries would also provide insights into how infrastructure, policy support, and cultural factors shape the adoption and sustainability of inclusive mobile technologies. Building on these directions, future work should also operationalize and validate the proposed IMCF introduced in this study. This framework integrates technological affordances, learning principles (mobile learning and UDL), and the social model of disability to conceptualize how mobile applications can systematically enhance accessibility and social inclusion. Empirical studies that apply and refine this framework in diverse contexts will help establish it as a robust theoretical and practical guide for inclusive mobile communication design.

8 ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study did not involve human or animal participants, so it did not require ethical approval. All methods used were in accordance with applicable institutional and international ethical standards.

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