Enhancing Accessibility for Sign Language Users

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Language serves as a powerful tool facilitating effective communication across diverse cultures globally. However, individuals facing language barriers, such as those with hearing disabilities, encounter difficulties expressing themselves to the world [15]. The existence of multiple sign languages worldwide compounds this challenge, as the unique gestures of each language create barriers to mutual understanding. To address this, people turn to mobile applications like Handtalk, Jeenie, and ASL Pocket Sign for communication and learning due to their affordability and accessibility [1, 6, 7]. Despite their benefits, challenges persist, including limited vocabulary signs leading to feature constraints, inconsistencies in displayed content, and a lack of multimedia utilization affecting user-friendliness, effectiveness, and performance [3]. Enhancing applications for barrier-free communication and addressing gaps in existing technology, the research focuses on the challenges individuals face due to the absence of suitable communication technologies, especially for those familiar with different sign languages worldwide [6]. A thorough analysis was conducted to address the identified issues with existing applications and platforms, examining their strengths, weaknesses, and areas for improvement through competitive analysis. Innovations were devised using research papers and innovative ideas from applications to improve overall usability and effectiveness. The proposed application stands out by offering a selection of multiple sign languages, including widely used ones like ASL, BSL, FSL, etc [18]. This approach eliminates the need for users to switch between different applications, distinguishing it from some existing solutions. Prioritizing globally used sign languages further enhances inclusivity in our application [18]. Introducing a live sign language translator, inspired by technology like Slait [19], revolutionizes video calls and meetings by providing real-time sign language translation into text captions, improving communication efficiency [19]. Unlike platforms using human translators, such as Jeenie [8], the proposed solution feature ensures user privacy and cost-effectiveness. Additionally, drawing inspiration from engaging platforms like Goodreads and Duolingo, we aim to overcome content limitations in existing applications. Our platform encourages user interaction and engagement by incorporating interactive individual and group activities and gamifying the learning experience [4,8]. These implementations aim to elevate the user experience and usability of the application. The research identified significant issues and system gaps, proposing solutions based on existing features in other domains. The subsequent sections will provide detailed insights into the literature review and the process behind these advancements.

CCS CONCEPTS • Sign Language Technology • Human-Computer Interaction • Accessibility & Usability • Mobile App Usability

Additional Keywords and Phrases: Assistive Application, Inclusive Technology, Gamified Learning, Artificial Intelligence, User-Centered Design

INTRODUCTION

Language serves as a powerful tool facilitating effective communication across diverse cultures globally. However, individuals facing language barriers, such as those with hearing disabilities, encounter difficulties expressing themselves to the world [15]. The existence of multiple sign languages worldwide compounds this challenge, as the unique gestures of each language create barriers to mutual understanding. To address this, people turn to mobile applications like Handtalk, Jeenie, and ASL Pocket Sign for communication and learning due to their affordability and accessibility [1, 6, 7]. Despite their benefits, challenges persist, including limited vocabulary signs leading to feature constraints, inconsistencies in displayed content, and a lack of multimedia utilization affecting user-friendliness, effectiveness, and performance [3].

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RELATED WORKS

While extensive research has delved into digital applications and user-focused solutions, our commitment is to align our proposals with existing studies. We strive to align our proposals with existing user-focused research, emphasizing empathy and understanding of users' needs and emotions [16]. This approach enhances the development of more useful and enjoyable products and services, fortifying the foundation of our solutions.

A significant study, "i-Sign: Sign Language Learning Application Via Gamification," presents compelling evidence for the effectiveness of gamification in enhancing learning experiences for deaf and hard-of-hearing children [16]. The study aimed to develop a mobile sign language learning application with gamification elements, following the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) model—an instructional design methodology [16]. The researchers created the application through meticulous iterations, conducting Usability Testing with eight students with hearing loss. The results affirmed the application's effectiveness, efficiency, and user satisfaction, achieving an impressive usability score of 91.89% [16].

Additionally, sign language still needs to be studied in multimodal communication. However, recent advances in deep learning present promising applications for neural networks in sign language mastery [2]. The study "AI at the Edge for Sign Language Learning Support" introduces a method for ASL alphabet recognition using Convolutional Neural Networks (CNN), enabling the monitoring of a user's learning progress [2].

This experiment utilized transfer learning and AlexNet for real-time image capture and classification [2]. Transfer learning adapted pre-trained models to specific data, while AlexNet, a convolutional network, facilitated image classification and label generation. Named "System Architecture: Real-time Image Capture and Classification," the application accessed the native camera, achieving promising results with an average accuracy of 33.9% (ranging from 17% to 65%). Participants, assessed with the System Usability Scale (SUS), expressed high satisfaction, averaging a score of 73.7, indicating a preference for this sign language learning application [2].

In conclusion, these studies showcase the potential of integrating gamification into sign language learning applications and harnessing AI, particularly CNNs, to support real-time sign language translation. The positive findings from these investigations contribute to the credibility of our proposed solutions, demonstrating their capacity to make learning more engaging and accessible for our intended audience.

PROPOSED SOLUTION AND PROTOTYPE

The widespread use of smartphones has enabled technological advancements that have created numerous sign language apps. Due to their affordability and accessibility, these applications are widely used. However, they vary in terms of their service, capabilities, and content [2]. The reason for choosing mobile apps is because the number and popularity of mobile apps are rapidly growing owing to the rapid use of smartphones, as well as other advantages such as their effectiveness, accessibility, portability, and convenience, not only for end users but also for developers who are urged to produce apps rather than web-based applications or computer programs [2].

Various applications offer sign language translation services from one language to another [2]. Therefore, if someone needs to use different sign languages simultaneously, they have to switch to different applications, which causes an inconvenience [9].

The idea is to create an application that supports many widely used sign languages and has a seamless translation feature. Users can choose their favorite sign language within this application. Users may use the app to decipher intended messages from people who speak various sign languages fluently. This can be achieved through real-time camera-based translation [13] or text input [1], which displays static or dynamic sign language symbols. Hence, the app will also translate from sign to spoken language [9].

Another feature we intend to incorporate into our application is a live sign language translator, primarily catering to meetings and video calls. This functionality allows users to engage in video calls or meetings, with the recipient receiving live text translations of the sign language communication [14]. Additionally, we are exploring the possibility of implementing a plugin that grants access to live text translation without requiring the use of the application. When using other video call platforms, our plugin seamlessly integrates and provides translation support independent of the platform [2]. Services like Jeenie offer human translators for various scenarios; however,

this can be costly and challenging to arrange on specific days [9]. Our application allows users to select from different sign languages, providing direct communication and reducing obstacles for individuals with disabilities.

Studies revealed that the existing sign language learning programs must be more interactive and engaging, resulting in decreased learning motivation [16]. The audience gets bored quickly if the interface does not interact [16]. Our proposal addresses this issue by making the application highly interactive and introducing different learning levels. Users will have the option to set their own learning goals, and this would be helpful for them in setting their objectives. Duolingo's bite-sized lessons and short competitions are highly motivating and entertaining. These approaches inspire the creation of similar engaging experiences for sign language learners. [5]. Because the existing system has minimal interfaces and is not appealing to the user [2], we plan to improve it by adding elements such as the point system, global leaderboard, learning with friends feature, etc. These will enhance the learning journey of the users. In addition, our application will provide rich multimedia content, video tutorials, and interactive exercises that will be created concerning user preferences [4]. To motivate the players, different events and friendly competitions can be added to the app [9]. Also, we are creating a community group for the users to join different communities, meet people, and share their learning experiences, just like on platforms like Goodreads [9].

In addition to offering students a more engaging and enjoyable learning environment than static content, gamification, and multimedia components help students become more focused during the learning process by drawing their attention to the learning activity [16]. It has been discovered that gamification increases user engagement, boosts user motivation, and improves performance. As a result, the app will have a gamified design to improve the user experience and make it more approachable, particularly for younger students [16].

The screen shown in Figure 1 is a medium-fidelity prototype of the application's Home screen. This screen provides users with three options to move forward. Firstly, the "Translate" option helps users to translate content. Secondly, the "Learn" option motivates users to learn more about other sign languages. Finally, the "Meet" option allows users to conduct meetings with captions to enable communication with others.

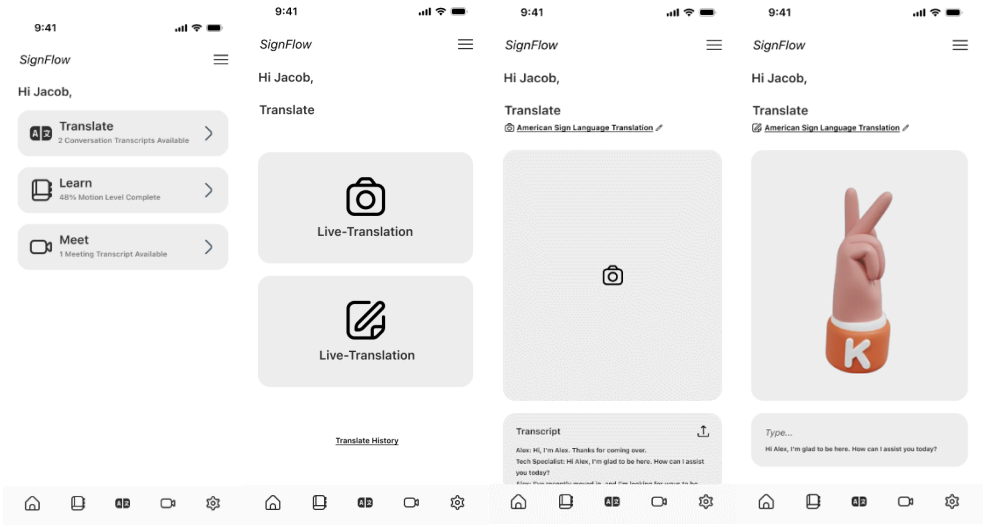

Fig.1 Homepage Fig.2 Translate Options Fig.3 Live Translation Fig.4 Text Translation

The Translate option has two sub-sections, as shown in Figure 2. The first is the Live Translation [13] feature, which captures sign language gestures through the camera, detects them, and translates them into text. The second is the Text Translation feature [1], which

allows users to translate written text into their selected sign language for communication, displaying static or dynamic sign language symbols.

We are exploring adding a plugin to our application that would enable live text translation even for other video call platforms. This plugin allows users to access translation services without relying on the application [2]. Unlike services like Jeenie, which offer human translators and can be expensive to book, our plugin provides seamless integration and translation support for users in different sign languages [9]. This feature will enable direct communication and reduce communication barriers, especially for disabled individuals.

Fig.5 Plugin on web

Research shows that sign language programs need to be more fun and engaging to help people stay motivated to learn [16]. Therefore, the application has been designed to offer an interactive interface with a playful nature and simple elements to not overwhelm the user. Figure 6 illustrates the learning page, which contains different options like daily practice, familiar words, and motion gestures for learning. The user can navigate between these options to learn various sign language topics. Figure 7 shows the different levels in which the users can learn, and each level unlocks once the previous level is completed. This can create a sense of motivation for the users and encourage them to complete each level and move to the next one. This helps the users learn quickly and retain their interest. Figure 8 depicts how the learning works for the different words, sentences, and sign language topics. There will be an interactive animation, audio instructions showing how to make the signs, and other sign language gestures enhancing the interactive learning experience. Users can also change the speed of the animation, which enables a detailed understanding of each sign and gesture. The “try it out” feature allows users to practice the gesture instantly without leaving the application by activating the front-facing camera.

Since the existing system has minimal interfaces and is not appealing to the user [2], the plan is to improve it by adding different elements such as the point system, global leaderboard, learning with friends feature, etc. Figure 9 shows the various competitions the user can join, and it is a point-based system in which participants can gain points based on their achievements. Points obtained by the user are displayed, and the “Leaderboard” option will provide the global point information. This gamification approach motivates the user and creates a better

learning environment for grasping sign language. It has been discovered that gamification increases user engagement, boosts user motivation, and improves performance [16]. Therefore, along with the gamification feature, these additional elements, such as vibrant colors and other interactive elements, will be added to the application in the next iteration. In addition, Figure 10 shows the "Groups & Friends" option, which will facilitate the users getting connected with other members and groups and help them create a community for collaborative learning and meeting new people interested in learning sign language. This aspect can enhance the overall learning experience.

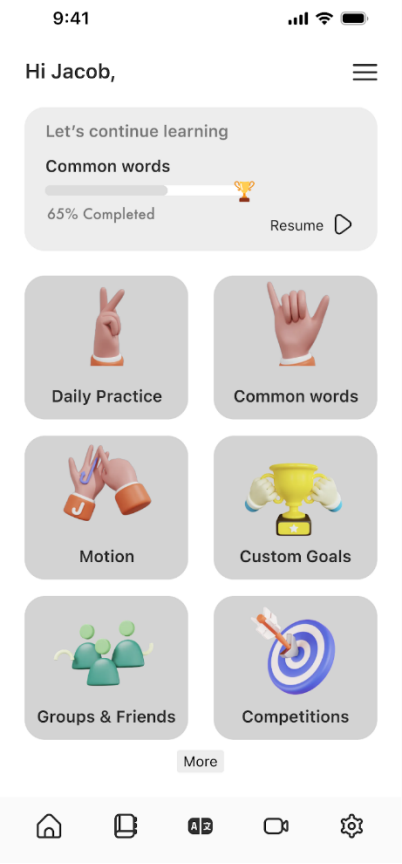

Fig.6 Learning page

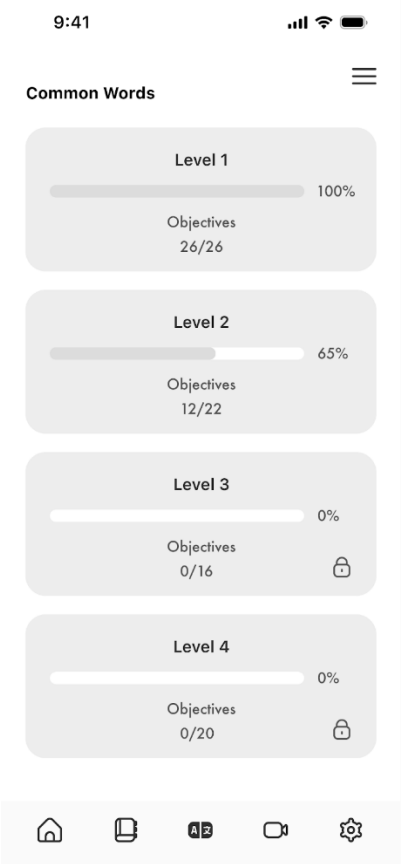

Fig.7 Learning levels

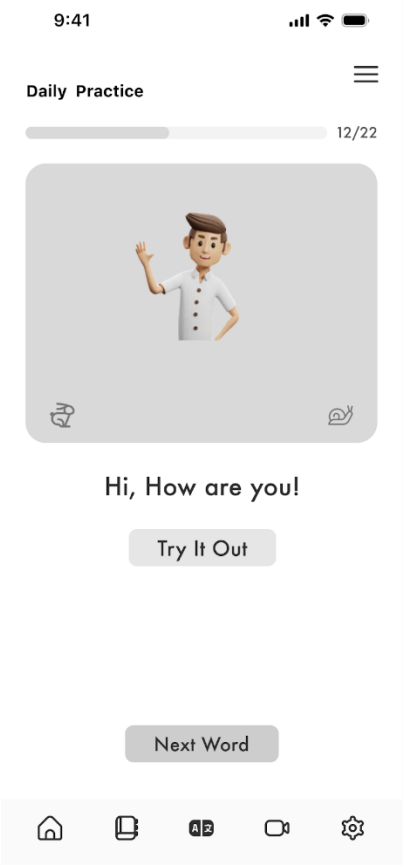

Fig.8 Learn & Practice page

Another prominent feature the application provides is the live translation during video calls. Services like Jeenie offer human translators for various scenarios; however, this can be costly and challenging to arrange on specific days [9]. The application allows users to select from different sign languages. During video calls using the application, users can turn on a feature for live translation, which will give live sign language to text translation. Figure 11 shows a live video call where one participant communicates using sign language, and the application translates that to text and displays it. This helps people with communication disabilities to talk with family and friends. Also, this enables them to talk with other people independently for work and different communication needs.

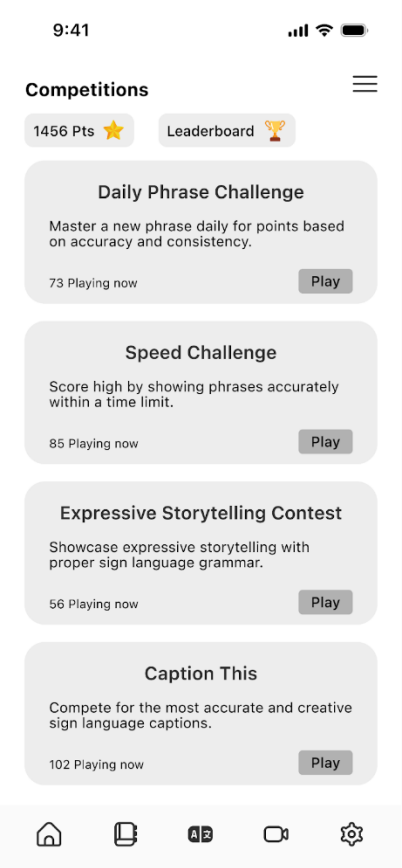

Fig.9 Competitions

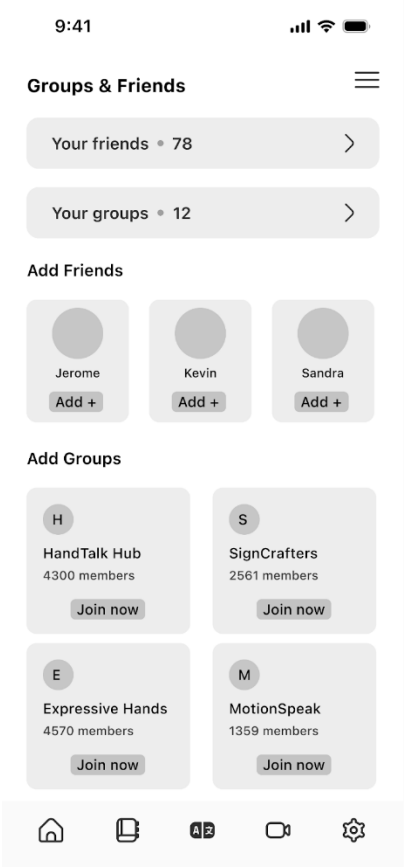

Fig.10 Groups & Friends

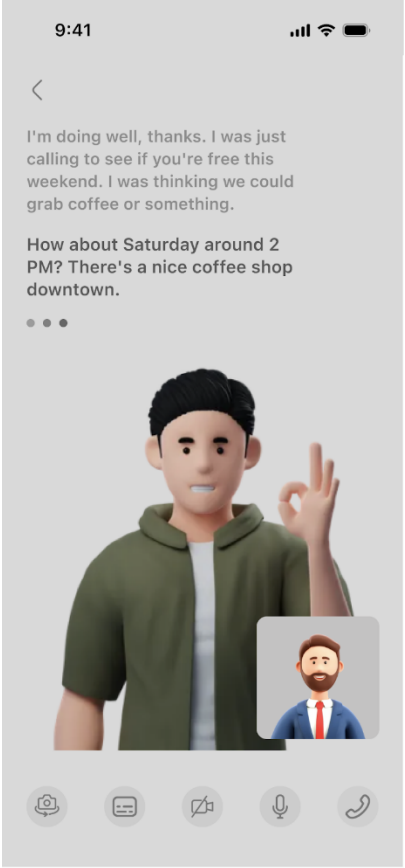

Fig.11 Translation during video call

LIMITATIONS AND FUTURE WORK

As described in the paper, the development of a mobile-based sign language translator on the Android platform introduces certain limitations. The exclusive focus on hand gestures may restrict the system's comprehensiveness, overlooking crucial elements like facial expressions and body movements integral to sign language interpretation [17]. The Android-centric approach may also limit the application to users on other operating systems.

Furthermore, challenges may arise during live video calls, especially if an incoming phone call interrupts the ongoing video conversation. Dexterity challenges may also affect users' ability to navigate the application effectively, impacting the overall user experience.

The proposed plugin for live text translation on other video call platforms may face space consumption and update challenges. Users might encounter difficulties in managing the plugin's space on their devices, and frequent updates may pose concerns for stability and

compatibility with various platforms. Poorly designed or outdated plugins can pose security risks, making the application vulnerable to exploits, data breaches, or malicious attacks. It's crucial to ensure that plugins undergo regular security audits.

Cultural compatibility is another aspect that needs attention, particularly concerning icons used within the application. Ensuring that icons are culturally appropriate and universally understandable is crucial to prevent potential misinterpretations or discomfort among users from different cultural backgrounds [6].

Recognizing the limitations associated with hand gesture recognition, especially when hands lack a direct line of sight with the controller, underscores potential accuracy and fidelity issues. Complex signs involving face or body contact may present challenges, particularly when performed closer to the face or top half of the torso [20].

Addressing the language barriers Deaf signers face on social media platforms, such as the lack of captioning and difficulty recording sign language, is essential. However, it's crucial to recognize that an English-centric focus in studies may skew data towards ASL users, limiting the inclusivity of findings to signers comfortable with English [10].

While mobile-assisted language learning (MALL) offers flexibility, its effectiveness as a complete replacement for traditional instruction may be limited. Affordability and accessibility challenges need consideration, particularly for learners in low-income or marginalized communities [12]. Additionally, the integration of text, audio, and video in mobile-based language learning (MMLSL) may face challenges related to small screen sizes and device vulnerability [11].

Navigating these multifaceted limitations requires a holistic approach, incorporating diverse technologies, user perspectives, and educational contexts. Future research should prioritize inclusivity, real-world applicability, and understanding the challenges within the dynamic landscape of sign language technology and education.

Future work on the sign language application should prioritize several key areas to address identified limitations. Firstly, enhancing the interpretation system by incorporating recognition of facial expressions and body movements will provide a more comprehensive understanding of sign language. Secondly, expanding the application's compatibility to include iOS and other operating systems will ensure a broader user base. Thirdly, implementing a user-friendly interface for individuals with dexterity challenges, including customizable touch gestures and voice commands, will enhance overall accessibility. Fourthly, improving stability during live video calls, especially managing interruptions like phone calls, is crucial for a seamless user experience.

Additionally, optimizing the live text translation plugin for space efficiency, regular updates, and compatibility across various video call platforms is essential. Ensuring culturally inclusive icons and conducting language studies beyond an English-centric focus will contribute to a more universally appealing and representative application. Furthermore, developing strategies for long-term user engagement, affordability initiatives for marginalized communities, and refining multimedia and Augmented Reality integration will contribute to a more effective and inclusive sign language learning experience. These proposed enhancements underscore the commitment to continuous improvement, accessibility, and user satisfaction in developing the sign language application.

CONCLUSION

In conclusion, the collective insights present sign language technology and education, as well as the progress and the persistent challenges that demand innovative solutions. The development of mobile-based sign language translators focusing on the Android platform signifies a commendable step forward, albeit with inherent limitations that necessitate careful consideration [17]. The identified sole focus on hand gestures introduces a potential hurdle to the system's comprehensiveness, neglecting elements like facial expressions and body movements integral to comprehensive sign language interpretation. Furthermore, the Android-centric approach raises concerns about potential exclusivity, limiting the application's accessibility to users on other operating systems.

Despite these challenges, the proposed solution promises a more inclusive and effective sign language application. Introducing real-time translation during video calls, inspired by successful technologies such as Slait [19], can significantly enhance communication efficiency. Likewise, the emphasis on gamification, drawing inspiration from successful applications like Duolingo [16], introduces an engaging and interactive dimension to sign language learning, addressing the recognized issue of decreased learning motivation [16].

Addressing challenges in live video calls, particularly interruptions and dexterity issues, is vital for user experience. Optimizing the proposed plugin for text translation on various platforms is essential, addressing space, updates, and security concerns. Cultural compatibility in sign language applications is crucial for universally understandable icons, preventing potential misinterpretations among users from diverse cultural backgrounds [6].

Limitations in hand gesture recognition and precise visibility issues highlight potential accuracy challenges [20]. Suggestions for improving body language and facial expressions represent a big step toward a more thorough comprehension of sign language. Expanding compatibility to include iOS and other operating systems is crucial for a broader user base.

Challenges in sign language technology on social media platforms emphasize the need for inclusive studies beyond an English-centric focus [10]. While mobile-assisted language learning (MALL) provides flexibility and accessibility, it may not entirely replace traditional instruction, especially for learners in low-income or marginalized communities [12]. Integrating text, audio, and video in mobile-based language learning (MMLSL) faces challenges related to small screen sizes and device vulnerability [11].

The proposed future work aligns with the identified limitations, presenting a comprehensive roadmap for substantial improvements. Enhancing the interpretation system, expanding compatibility, improving accessibility, and strengthening stability during live video calls represent crucial steps toward refining the user experience.

The proposal of the live text translation plugin for space efficiency, regular updates, and compatibility reflects user-friendly functionality and heightened security. Ensuring culturally inclusive icons and conducting language studies beyond an English-centric focus contribute significantly to a more universally appealing and representative application. For long-term user engagement, affordability initiatives for marginalized communities and the refinement of multimedia and AR integration underscore a commitment to continuous improvement, accessibility, and user satisfaction.

The collective findings of sign language technology and education urge researchers and developers to adopt a comprehensive and inclusive approach. The proposed improvements and future directions outlined in these studies contribute to the evolution of sign language applications, signifying a dedicated pursuit of meaningful and accessible communication solutions for individuals with hearing impairments.

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