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PAPER

Mobile Application Design Oriented to Students with Deaf Mute Disabilities

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ABSTRACT

Deaf-mute individuals have a right to inclusive education in today's global context. The primary objective of this study is to design a mobile application that caters to the specific needs of students with hearing and speech disabilities, contributing to the promotion of inclusive and equitable education. To conduct this study coherently, the effective Design Sprint methodology was employed, consisting of five well-defined phases. Throughout this process, interviews and surveys were conducted with various stakeholders, including students, parents, and specialists in inclusive education. The results of these investigations formed a robust foundation for understanding user needs and perspectives, ensuring the optimal adaptation of the mobile application to the demands of this demographic. In conclusion, this study underscores the importance of creating inclusive solutions for students with hearing and speech disabilities, emphasizing the need for collaboration and commitment from educational authorities to successfully implement such solutions.

KEYWORDS

deaf mute, design sprint, disabilities, inclusive education, mobile application

1 INTRODUCTION

Mobile technology is having a major impact on the way we communicate and access information, and this is particularly relevant for people with deaf-mute disabilities. The development of mobile applications focused on students with this disability can represent a valuable tool for improving communication, independence, and inclusion in the educational setting. This paper addresses the design of mobile applications for students with deaf blindness, identifying the challenges and opportunities associated with this task, and presenting some examples of previous work conducted internationally. In addition, the potential benefits that these applications could offer in terms of inclusive education will be examined. Furthermore, the design of mobile applications oriented to students with deaf-mute disabilities is a topic of importance today. People with this disability face several barriers in their

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educational process, which hinder their access to information and their participation in the classroom. A mobile application designed specifically for this group can help remove these barriers and improve their educational experience. So, we will explore some important aspects of designing mobile applications for students with deaf-mute disabilities and how these can improve their learning process.

Mobile applications for sign language (SL) are a fascinating area of research that deserves more attention. Although these apps are widely used due to their affordability and ease of use, it is important to assess their quality for them to have a significant impact [1]. A systematic literature review conducted in four academic databases highlighted that SL applications need further development to improve the user and learning experience. To address this need, a solution framework based on quality evaluation criteria was presented that could be used by academics and developers. The results demonstrate that this approach can establish a detailed set of criteria for the development of SL mobile applications, which benefits future academics and opens a new field of collaboration between researchers and developers.

Numerous nations have emphasized the inclusion of hearing-impaired citizens in all aspects of social life. Despite the use of SL, this population continues to face problems communicating with others. SL applications are being created to bridge the communication gap thanks to technological advances that allow for the widespread use of smartphones. These apps are widely used due to their accessibility and low cost, but the quality of the content and services they provide varies significantly. It is necessary to evaluate the quality of the content provided by these apps to have a real effect on the communication of people with hearing impairments [2]. A thorough evaluation will inspire developers to work on new applications, improving the overall software experience and development.

The authorities have not paid enough attention to people with hearing loss, which has left these patients confused about which learning media to use to interact with their social environment. To address this challenge, a mobile application called "Deaf Assistant" has been developed. This application aims to help people with hearing loss to be understood through SL [3]. The application has several functionalities, including registration, interactive videos, SL translator, forums, customer service, library, information, history, events, donations, and stores. Use case diagrams and class diagrams modeling the database were used for its design, and its implementation was done using Android Studio and MySQL.

The importance of SL in improving communication between hearing impaired and non-hearing impaired people. However, due to the large number of SLs with variations, automatic sign language recognition (ASLR) has become complex. Researchers are looking for more effective ways to develop ASLR systems, which have proven to be successful [4]. In this paper, research on intelligent systems for SL recognition over the past two decades is reviewed. A total of 649 publications related to intelligent SL recognition systems were analyzed using bibliometric software. Reviews of SL recognition techniques are presented, and various feature extraction and classification techniques used in SLR are discussed. It is concluded that incorporating intelligent solutions in SL recognition systems is crucial, and work remains to be done.

Disability is a condition that affects many people around the world, including Indonesia. People with hearing impairments, in particular, face significant challenges in their education, especially in communicating with their teachers and classmates [5]. Although several mobile applications have been developed to assist students with hearing impairment, many of them are in English and do not provide adequate visualization of objects, making comprehension difficult. To address this

problem, a new mobile application has been developed that uses Google's speech-to-text recognition technology in Indonesian to translate speech into text and display images of objects and their colors. This app offers a fun and effective alternative for deaf students to learn and can be used by students, teachers, and parents alike.

However, deafness can create significant obstacles in the educational environment, as it impedes effective communication and limits full participation in educational activities. However, mobile apps specific to students with deaf disabilities have the potential to overcome these barriers and improve the educational experience of these students. In addition, these applications can also promote inclusion and independence, allowing students to access information and participate on an equal footing with their classmates. Given the importance of mobile technology in everyday life, it is crucial to address the need to design mobile applications specific to students with deaf disabilities. This article seeks to justify this importance and present a detailed discussion of the challenges, opportunities, and recommendations for the design of these applications.

The mobile solution is the design of accessible, usable, and inclusive-designed applications for students with hearing and speech disabilities. Accessibility implies compatibility with assistance technologies, such as voice recognition and Braille keyboards, and considers visual needs. Usability is ensured through intuitive and well-organized interfaces for easy understanding and access to information. Inclusive design considers different SLs, customization, and user-to-user communication. The aim is to promote the inclusion and independence of students, allowing them to access and participate on an equal footing. The application should be accessible, easy to use, and include inclusive design features. Consider different SLs, Customization and communication between users are essential. The interface should be clear and intuitive. In short, the aim is to design a mobile application that meets the needs of students with hearing and speech impairments.

2 LITERATURE REVIEW

The design of mobile applications for students with hearing and speech disabilities is an important topic today. Existing literature highlights the importance of accessibility, usability, and inclusive design to ensure that students with disabilities can access education and communicate effectively with their peers and teachers. The following are some of them. People with hearing impairments experience a negative impact on their daily lives, as well as on the people around them. Although various technological tools have been developed to reduce this impact, most current mobile applications using speech-to-text technology are inconsistent, as they do not include all types of hearing impairment, work only in predefined environments, and do not allow for multi-participant conversations. This makes current tools less effective and makes hearing-impaired participants feel excluded. This paper proposes a model to solve this problem using multi-participant classification technology in the design of mobile applications for the hearing impaired [6] [7]. A new mobile application called Deaf Chat that uses this model is also presented. The results of a survey indicate that users accept this new platform well and that it could be very useful in improving the quality of life of hearing-impaired people. The evolution of technology has enabled greater connections between people and has generated new educational and social opportunities. However, people with disabilities continue to face social barriers in the implementation of accessible hardware and software that enable them to access information and opportunities, as well as to care for their environment. A study in

Korea sought to understand the lives and communication of people with hearing impairments and to identify problems and design possibilities. An unstructured individual interview was conducted with four participants, and the data were systematically analyzed [8]. A prototype sound alert was produced using Arduino to support their independent living. The interview and analysis method were successful, and the contents will serve as guidelines for future designs.

The fundamental right of every human being is to have equal opportunities [9] [10]. To achieve this, deaf society needs to have unrestricted access to information just like hearing people. To achieve this, direct communication between deaf and hearing people is needed, and this must be automated so that deaf people are not dependent on human interpreters [11]. This article discusses different projects of machine translation and SL generation. A systematic review of the existing literature was performed and classified into different categories, with their advantages and limitations. More efforts are needed to improve the methods of translation and sign presentation to make communication easy and comfortable for the deaf society. In addition, advanced technologies such as deep learning and neural networks should be included to improve the translation process between text and sign language.

Millions of students worldwide have had their education disrupted due to the COVID-19 pandemic. To investigate deaf students' perceptions of online distance education and accommodations provided during the pandemic, a qualitative study was conducted using anonymous semi-structured interviews [12]. In June 2020, a convenience sample of 15 deaf students and three instructors were interviewed, and responses were analyzed thematically. The analysis revealed five main themes related to deaf students' experience of online distance learning during the pandemic: course content, technology used, delivery method, assessment tools, and lack of social interactions. Students described their experience both positively and negatively, and instructors also shared their experiences. Although online distance learning presented challenges, it also improved participants' technology skills and ability to adapt to a new environment.

Due to the increasing use of distance learning platforms in educational institutions, instructors of deaf students have faced the limitation of not having a specialized platform that allows them to deliver learning content remotely for deaf students through videos with sign language translation (SLT) [13]. This study proposes the use of a new asynchronous distance learning platform for deaf students with special features that would help instructors of deaf students to develop and deliver educational materials remotely. The study involved 19 educational technology experts, seven instructors for deaf students, and 16 deaf undergraduate students, who evaluated the proposed platform through online questionnaires. The findings of the study suggest that the platform is suitable for distance learning and that deaf students could easily access and study courses remotely with the help of the proposed platform.

Digital learning has become a necessity due to the COVID-19 pandemic and can help students in the teaching and learning process. Although face-to-face teaching of technical and vocational education and training (TVET) is more practical than online teaching, teachers have had to provide excellent online education [14]. A study was conducted at the Malaysian Public University to examine the need for a digital learning framework on TVET. The data analyzed showed that lecturers' knowledge about online teaching and learning is moderate, while knowledge about digital learning is high. Higher education stakeholders could use the findings to develop a framework on digital learning in technical and vocational education and training.

Deaf and hard-of-hearing people use SLs to communicate in their daily lives. However, communication with hearing people is still hindered due to the lack of

knowledge of SLs by hearing people. Therefore, it is important to foster tools that enable communication between sign or spoken language users [15]. The SLT task is an opportunity to produce spoken language translations of a SL video and vice versa. The implementation of translators on handheld devices will move towards barrier-free communication between DHH and hearing people. This paper reviews the SLT literature, provides background on SL, and describes datasets and results found in the literature for one of the most widely used datasets, the RWTH-PHOENIX-2014T. In addition, challenges to be addressed in SLT research are listed and future lines of research are proposed.

Pattern recognition technologies have multiple applications, one of which is the development of real-time SL interpretation systems, which is especially relevant for deaf-mute people who represent 5% of the world's population and who do not always have access to a live interpreter. Moreover, 80% of hearing-impaired people live in low- and middle-income countries, so the development of low-cost systems would be beneficial for their social integration [16]. This paper proposes an algorithm based on the palm definition model and linear models to recognize number and letter forms of Kazakh SL, which would significantly improve the recognition capability of existing systems.

Deaf people experience varying degrees of hearing loss and primarily use SL to communicate. This can be a great challenge during emergency situations, as most emergency services rely on oral communication [17]. Therefore, there is a need to design a mobile application to support emergency signaling for deaf people. The application, called Sign Support, was developed in collaboration with local deaf communities, emergency service providers, and experts in the field. The app was rigorously tested and found to be effective and useful by stakeholders, thus ensuring that deaf people have equal access to emergency services as people who can hear.

The main communication language of deaf people is the signing language. Efforts to create SL generation systems can make life easier for these people. Despite the relevance of SL generation systems, a rigorous review of research is lacking. This is the most well-known academic review on SL generation systems. It includes a database of academic literature from 1998 to 2020, as well as classification standards for systematizing research. 444 research studies were identified and reviewed for their direct relevance to SL generation systems. Subsequently, 172 research studies were selected, reviewed, and classified. Each of the 162 selected research papers was classified according to 30 SLs and then compared using seven comparison criteria (input form, translation technologies, scope, use of syntax and grammar analyzers, manual and non-manual characteristics, precision, and output form) [18] [19]. According to our conclusions, most research on SL production has been carried out using data-based methodologies in the absence of adequate grammar rules and has generated only manual signs. This research study can provide researchers with a road map for future research areas and contribute to data accumulation in the field of SL creation.

People who are deaf or hard of hearing use SL to communicate on a daily basis. However, communication with hearing people still faces certain challenges due to the lack of information about SLs on the part of hearing people. Therefore, there is a need to support methods that enable communication between sign or spoken language users. Research into SLT work, which attempts to provide a spoken language translation of a film into SL or vice versa, is a step in this direction. If we include such translators in portable devices, we will move significantly towards barrier-free communication between hearing and non-hearing-impaired people [20]. Therefore, this study focuses on reviewing the SLT literature and providing the necessary foundation on SL. In addition, for one of the most widely used datasets, the

RWTH-PHOENIX-2014T, we summarize the available datasets and findings published in the literature. In addition, the study identifies obstacles that need to be addressed in SLT research as well as in the application of SLT technology and suggests future research directions.

In India, people with hearing and speech impairments often use Indian Sign Language (ISL) to communicate. Unlike spoken language, SL uses visual signals such as hand movements, arm posture, hand orientation, and facial expressions to convey the message of the speaker. For most communication situations, video calls are used, which are increasingly common in contemporary culture. Persons with disabilities may find it difficult to communicate during videoconferencing due to their limited ability to express themselves. It is therefore crucial to translate SL into a universally understandable language [21]. The proposed application aims to bridge the communication gap between deaf and hearing-impaired communities and the rest of society. Our study presents a technique for acting-based SL recognition. The CueAid application has two main functions: translate voice to gesture and convert gesture to text. It records movement using OpenCV, identifies critical points using Media Pipe, and recognizes dynamic signs using a specially trained long-term memory model (LSTM). The study used a unique data set of 15 everyday American Sign Language (ASL) sentences with an impressive average accuracy of 93.33%. The resulting model can be integrated into the application for immediate ASL recognition.

In this syntax, the literature review supports the idea of mobile application design oriented to students with deaf and mute disabilities that plays a significant role in Peru because it is very important to implement a mobile application that assists people or students with deaf and mute disabilities. In summary, we have a conclusion that for the topic Design of mobile applications oriented to students with deaf-mute disabilities, there is very little research on the subject, which is why the present study will contribute to helping a little more in the development of research. These applications provide us with an accessible, efficient, and complete platform and are based on being able to help people with deaf-mute disabilities, where people with disabilities can have the facility to interact with other people.

3 METHODOLOGY

This section describes in detail the steps to follow for the implementation of the mobile application. In addition, in the development part, the creation of the prototype designs was carried out using the Figma technological tool, and, at the same time, the agile methodologies design sprint consisting of five phases was implemented.

3.1 Methodology design sprint and phases

A) **Analysis:** In this initial phase, a comprehensive analysis is conducted to understand the needs and requirements of the target users, who, in this case, are students with hearing and speech disabilities. Specific steps may include:
   i) Participant selection: Select 10 individuals for interviews, in this case, parents of deaf-mute students. Ensure the sample is diverse to gain a representative perspective.
   ii) In-depth interviews: Conduct in-depth interviews with parents to gather insights into the needs, challenges, and expectations of deaf-mute students (refer to Table 1).

Table 1. In-depth interview questions

Dimension	Questions
Usability and Accessibility	What are the most significant challenges your children with hearing and speech disabilities face when using mobile applications? What features or elements in a mobile application do you believe would be most useful and accessible for your children with these disabilities? How would you assess the ease of use of a mobile application designed for your children? What aspects would you consider important in terms of usability?
Educational Content and Communication	What type of educational content or communication tools do you consider essential to support your children in their academic and social development through a mobile application? What are the main barriers you have encountered when looking for mobile applications for your children with hearing and speech disabilities? What communication or interaction features between students, parents, and teachers do you believe would be valuable in a mobile application designed for these purposes?
Parental Experience and Involvement in Design	What role do you think parents should play in the design and development of a mobile application aimed at students with hearing and speech disabilities? What would be the ideal way to keep parents informed about the progress and usage of the mobile application by their children? What advice or suggestions do you have for designers and developers working on mobile applications for students with these disabilities?

iii) Data collection: Record and analyze interview responses to identify common patterns and trends in user needs and preferences.

B) **Ideation:** In this phase, the focus is on generating creative ideas to address the challenges identified in the analysis phase. Specific steps may include:

i) Brainstorming session: Organize a brainstorming session where participants can propose solutions to the problems identified in the previous phase.

ii) Use of generative questions: Pose generative questions to stimulate creativity and help participants think of innovative solutions (refer to Table 2).

Table 2. Generative questions and ideas based on the answers

Interview Questions	Ideas Based on the Answers
What are the main concerns you have regarding the education and development of your hearing and speech impaired children?	Develop a mobile application that focuses on effective communication and sign language to support students in their daily interaction.
What technological challenges have you faced in supporting the education of your children with these disabilities?	Create an educational platform that integrates content specifically for students with hearing and speech disabilities, including interactive lessons and teaching resources.
What features of a mobile application would you consider essential to meet the educational and communication needs of your children?	Implement a progress-tracking feature that allows parents and teachers to stay informed about students' academic development.
How do you see your involvement in the process of designing a mobile application for students with hearing and speech disabilities?	Provide a library of resources and useful links within the app for parents to access relevant information.
What mobile apps or technology resources have you found most effective in helping your children so far?	Facilitate interaction between parents, teachers, and students through a real-time communication feature.

(Continued)

Table 2. Generative questions and ideas based on the answers *(Continued)*

Interview Questions	Ideas Based on the Answers
What specific type of educational content do you think would be most beneficial to your children through a mobile app?	Incorporate customization options in the app to suit individual student needs.
How would you evaluate the accessibility and usability of a mobile application designed for your children?	Ensure accessibility of the application, with the ability to adjust text size, set voice preferences, and provide screen-reading options.
What recommendations would you have for mobile app designers and developers who want to create effective tools for students with these disabilities?	Provide in-app tutorials and training resources to help parents get the most out of the platform.
How would you like to stay informed about your children's progress and use of the mobile application?	Encourage active parent participation in the design and testing of the app through feedback groups and ongoing evaluations.
How do they envision the positive impact a mobile app could have on the educational and personal lives of their hearing and speech impaired children?	Keep parents informed about app updates and enhancements through regular notifications and clear communications.

C) **Decision Making:** At this point, the goal is to refine and select the best ideas generated during the ideation phase. Specific steps may include:

i) Idea evaluation: Assess the ideas generated in terms of their feasibility, effectiveness, and suitability to meet user needs.

ii) Consensus and idea fusion: Facilitate a consensus process where participants choose the most promising ideas and merge concepts if necessary.

Based on the questions asked in the previous stage or the brainstorming session, the following activities are decided upon (refer to Table 3).

Table 3. Idea evaluation

Activities	Ideas
Iterative Prototype Design:	Create prototypes of the mobile application and iterate based on feedback from parents and accessibility experts to improve usability and accessibility.
Usability Testing with Parents and Students:	Conduct usability testing with parents and students to assess the effectiveness and ease of use of the mobile application in a real-world setting.
Development of Interactive Educational Content:	Develop interactive educational content specific to the mobile application, tailored to the needs of students with hearing and speech disabilities.
Parent Training Sessions:	Offer application training sessions for parents so they can effectively support their children in using the mobile application.
Accessibility Assessment:	Conduct regular accessibility assessments on the mobile application to ensure it complies with accessibility guidelines and standards.
Beta Testing with Parent Community:	Launch a beta version of the application to a group of parents and gather their feedback and suggestions before the official release.
Ongoing Updates and Communication:	Keep parents informed about updates and improvements to the application through notifications and feedback, ensuring the application remains relevant and effective.

D) **Prototyping:** In this phase, a prototype of the mobile application is created based on the decisions made in the previous step. Specific steps may include:
   i) Prototype design: Use the selected ideas to design prototypes of the mobile application. This includes creating user interfaces, navigation flows, and visual design.
   ii) Internal usability testing: Conduct internal testing to ensure the prototype is functional and meets the requirements before moving on to the testing stage.

E) **Testing:** In this final phase, the application prototype will undergo testing to assess its effectiveness and gather feedback. Specific steps may include:
   i) User satisfaction survey: Administer a survey to the target users, in this case, deaf-mute students, to evaluate their satisfaction with the prototype.
   ii) Mobile expert validation: Consult mobile app design experts to evaluate the usability and accessibility of the prototype.
   iii) Health specialists' surveys: Seek input from healthcare specialists, such as speech therapists or professionals in the field of hearing disabilities, to ensure that the prototype meets the need of these users.

3.2 Development tools

The authors [22] [23] state that Figma is one of the design tools that is often used to create the appearance of mobile desktop applications, websites, and others. Figma can be used on Windows, Linux, or Mac operating systems connected to the Internet [24]. Figma has the advantage that the same job can be done by more than one person at a time, albeit in different locations. This can be said to be group work, and thanks to the ability of the Figma application, this is what makes this application the choice of many UI/UX designers to create prototypes of websites or applications quickly and efficiently [25]. So, the author [19] manifests that Figma is a tool to create prototypes of websites or mobile applications, which stands out for its intuitive functionality and its ability to allow teamwork in real-time. In addition, it is hosted in the cloud and has add-ons that improve the visualization of the design. It can be used from the browser or download the application to the computer. In short, it is a complete and versatile solution for online prototyping.

3.3 Prototype development

In this section, we developed the prototypes of the mobile application, which will have several prototypes so that the user can access and register. Also, as development of the prototypes, we have nine prototypes, in which in each figure two prototypes will be implemented where they will have their respective descriptions. And the explanation of what each prototype is for or what its functionalities are.

Likewise, in the development of the prototypes, as shown in Figure 1, the main screen is the title of the app. The student will have access plus the user registration, where you can register with your email, your name, your username, and set a password. This procedure is in case you do not have a registered account so that at the time of registration you have access to the app.

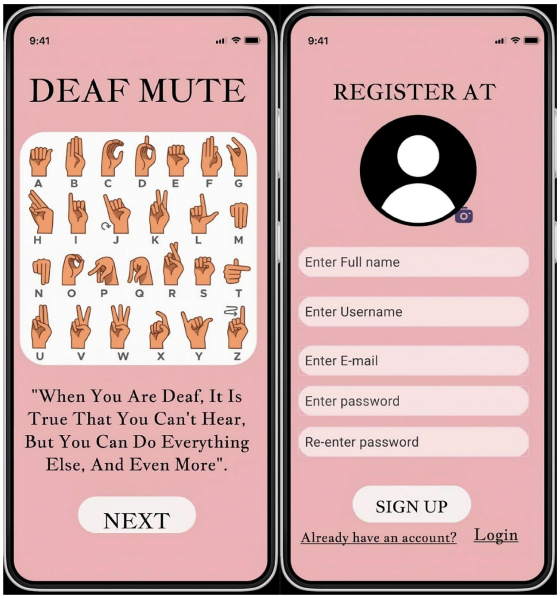

Fig. 1. Application startup plus user registration

In the development of Figure 2, we can see the implementation of the development of the login where the user, after registering, has the option to log in since they would enter their user name plus password; in case the user forgets the password, they have the option to recover the password. Also, after logging in and entering the app, the user would have the option of search types where they would find educational games, plus SL to communicate with people with deaf-mute disabilities, or they would have the facility to be able to communicate with us.

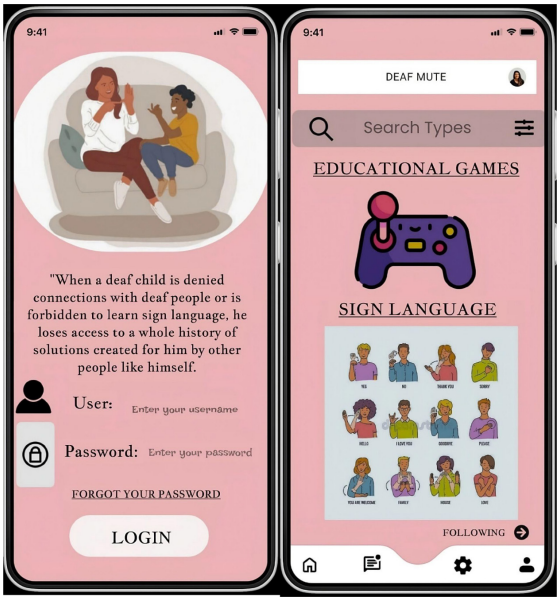

Fig. 2. Login more search type

In the development of the prototype in Figure 3, the user will have educational videos where they can choose whether to watch the Alphabet of Signs video or the step-by-step coloring video. Then they will have the option to learn a little more about SL. This course is for all people who log in so that we can communicate with

people who suffer from deaf-mute disabilities. In turn, we can also learn a little more about how to express the sensations or emotions they feel.

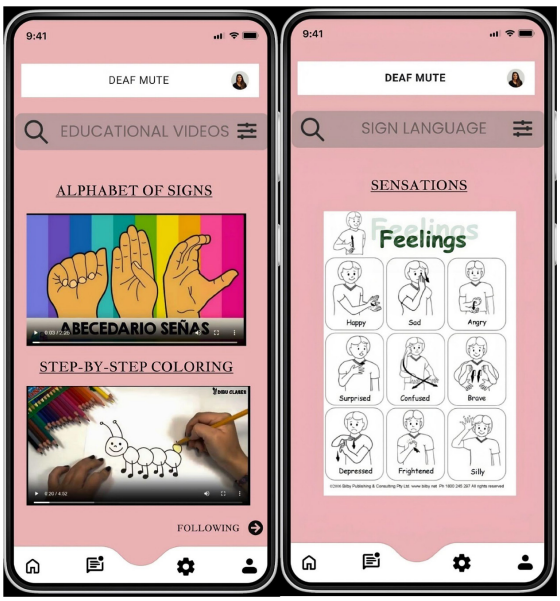

Fig. 3. Educational videos plus sign languages

In the development of the prototypes in Figure 4, we can see that after learning the SL courses, we also have other courses, such as the days of the week in SL, so that we can communicate with them or they can communicate with us. We can also learn the vocabulary so that we can understand if they are making jokes or telling us if we are being polite. Also, the user will have the option to go to settings, where you would have several options, such as editing the user profile.

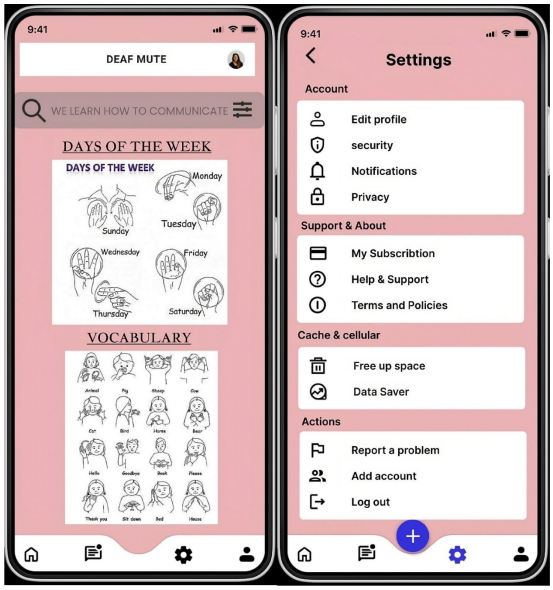

Fig. 4. Learn to communicate more app settings

In the development of the last prototype in Figure 5, we have that the user after going to the settings section will have the option to edit his profile, where they will

have the options to modify their name, email, password, birthday, and country or region. After modifying, there is a button where the user can save the changes to edit the profile.

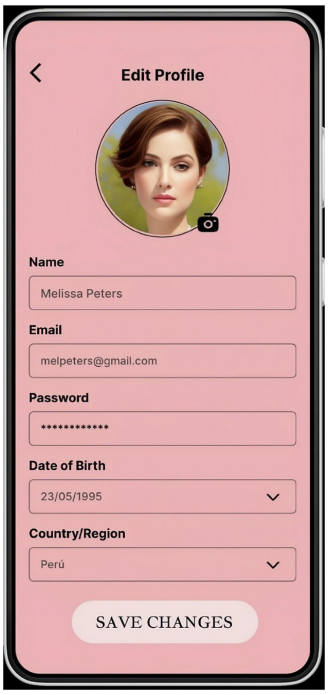

Fig. 5. Edit user profile

4 RESULT AND DISCUSSIONS

4.1 About the interview

The interviews conducted with 10 relatives of deaf and mute individuals provide valuable insights within the three key dimensions. First, in the "Usability and Accessibility" dimension, there is a clear need for improved accessibility in mobile applications for the deaf and mute, including subtitles, SL features, and customization. The interviews highlight the challenges these individuals face when interacting with non-adapted interfaces. In the "Educational Content and Communication" dimension, relatives emphasize the importance of adapted educational content and communication tools that enable effective participation in learning and social interaction. Additionally, the lack of specific applications and accessibility options is identified as a significant challenge in this dimension. Finally, in the "Parental Experience and Involvement in Design" dimension, interviewees underscore the importance of involving parents in the design and development of mobile applications for the deaf and mute. They suggest that parents should be consulted from the outset and have access to tools that allow them to track the progress and usage of the applications by their children. The interviews reveal the need for more accessible mobile applications with specific educational content and a focus on active parental involvement. These insights are crucial for improving the quality of life of deaf and mute individuals and their access to education and communication (see Figure 6).

The interviews with hearing and speech disabilities provide valuable insights into three fundamental dimensions of mobile application design for this group.

In the "Usability and Accessibility" dimension, there is a clear demand for increased accessibility, including features such as subtitles, SL support, and customization. These interviews reveal the challenges these individuals face when interacting with interfaces that don't cater to their specific needs. Moreover, studies such as [7] have demonstrated that the lack of effective and accessible tools for people with hearing and speech disabilities in mobile applications poses a significant barrier. In the "Educational Content and Communication" dimension, the critical importance of personalized educational content and effective communication tools for learning and social interactions is underscored. Recent research [8] has also focused on the use of AR technology to support individuals with hearing impairments, emphasizing the growth of innovative approaches. In the "Parental Experience and Involvement in Design" dimension, the pivotal role of parents in the design and development of mobile applications is emphasized. These recommendations have been highlighted in various studies, including [9], which advocate for active parental collaboration to promote direct communication and enhance the lives of this group. The integration of these insights and recommendations into mobile application design can have a significant impact on the lives of individuals with hearing and speech disabilities, promoting equal opportunities and access to information and communication.

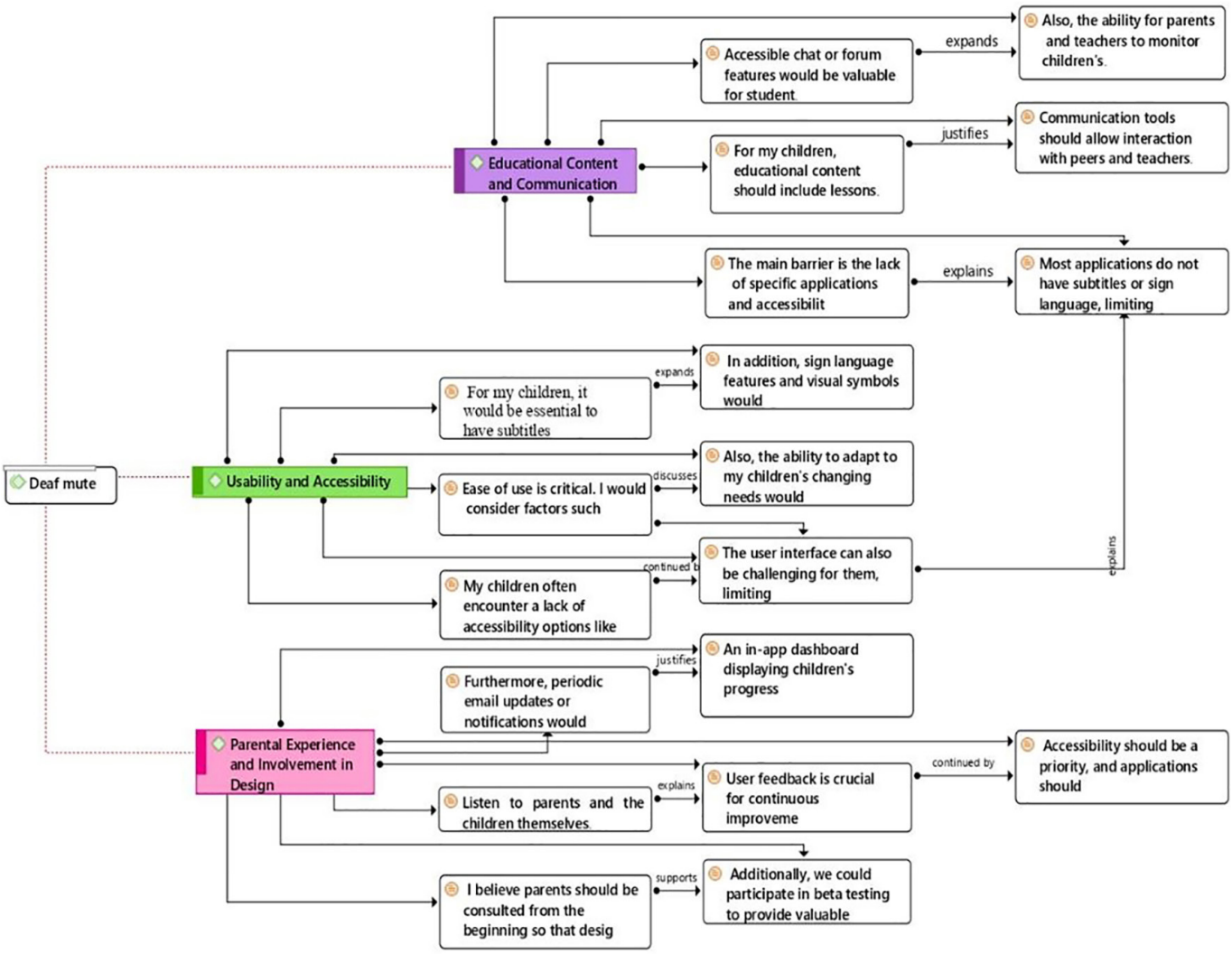

Fig. 6. About the interview Atlas.ti 22

4.2 User satisfaction survey

Satisfaction survey for mobile application for 50 deaf-mute students, with dichotomous yes or no answers:

Q1. Is the mobile application easy to use and navigate?
Q2. Do you find the mobile application accessible and user-friendly for the deaf-mute users?
Q3. Has the mobile application helped you communicate and learn more effectively?
Q4. Do you consider the educational content in the application to be relevant and useful for your learning?
Q5. Have you experienced an improvement in communication with teachers, parents, or other students through the application?

To visualize the results of the satisfaction survey for the mobile application designed for deaf-mute students, a stacked bar chart has been generated. The data reveals that, overall, the majority of the surveyed students hold a positive perception of the application in most of the evaluated areas. Specifically, around 60–80% of the students responded "Yes" to questions regarding ease of use, accessibility, improvement in communication, and the relevance of educational content. However, there were some areas where "No" responses were also significant, such as the relevance of educational content, where approximately 44% responded negatively. These results suggest that, while the majority of students see benefits in the application, there are areas for improvement, particularly in educational content (see Figure 7).

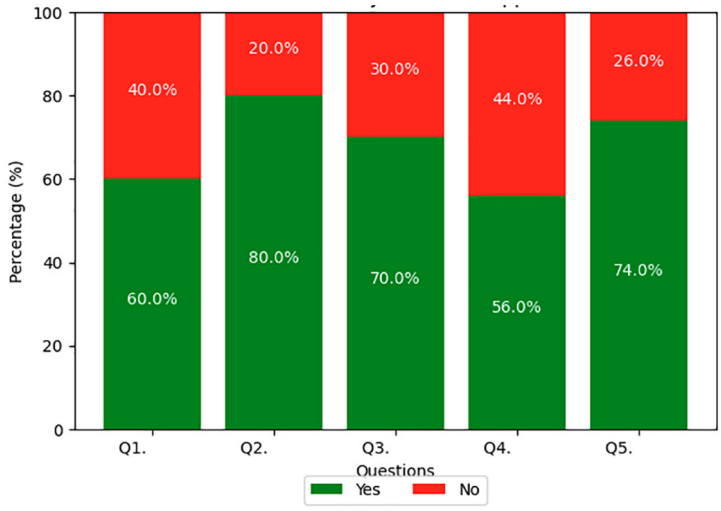

Fig. 7. User satisfaction survey

4.3 Health specialist's surveys

Question 1. Do you believe that mobile applications can be an effective tool to enhance communication and learning for students with deaf-mute disabilities?
Question 2. Do you think that current mobile applications adequately meet the needs of this population in terms of accessibility and usability?

Question 3. Do you consider interdisciplinary collaboration between healthcare professionals, educators, and developers is essential for designing effective mobile applications for these students.
Question 4. Do you support the idea that mobile applications should offer SL communication and text-to-voice translation features to facilitate interaction for students with deaf-mute disabilities?
Question 5. Do you believe that mobile applications can play a crucial role in the inclusion and support of students with deaf-mute disabilities in educational settings?

The survey results from 30 healthcare specialists provide diverse perspectives on the potential of mobile applications in the education of students with deaf-mute disabilities. In the first question, 60% of specialists support the idea that mobile applications can serve as an effective tool to enhance communication and learning for these students, while the remaining 40% have reservations. The second question reveals that 33.3% of specialists believe that current mobile applications do not adequately meet the accessibility and usability needs of this population, in contrast to the 66.7% who maintain a more optimistic outlook. The third question reflects that 63.3% of specialists value interdisciplinary collaboration among healthcare professionals, educators, and developers as essential for designing effective applications. Regarding the fourth question, 56.7% endorse the idea that mobile applications should offer SL communication and text-to-voice translation to facilitate interaction. Finally, in the fifth question, 53.3% of specialists believe that mobile applications can play a pivotal role in the inclusion and support of students with deaf-mute disabilities in educational settings. These results underscore the importance of addressing accessibility in mobile applications and promoting interdisciplinary collaboration to develop effective solutions within the context of inclusive education (see Figure 8).

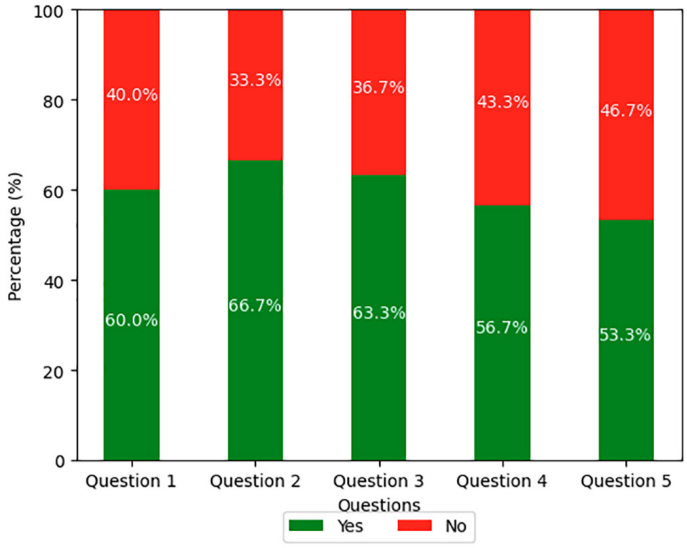

Fig. 8. Health specialist's survey

4.4 Mobile experts validation by criteria

a) Accessibility and usability (AU): Experts should assess whether the application complies with accessibility standards, such as adherence to the WCAG (Web

Content Accessibility Guidelines) for mobile applications. Additionally, they should consider usability, ensuring that navigation and interaction are intuitive and efficient for deaf-mute users.

b) Educational content and communication (ECC): Experts should review the quality of educational content and its suitability for deaf-mute users. They should assess whether the application facilitates effective communication in SL and provides resources that promote learning and language development.

c) Visual design and multimedia (VDM): They should evaluate the visual design of the application, including text legibility, color contrast, and the quality of images or videos used. Furthermore, they should ensure that any multimedia content is subtitled or has SL interpretation.

d) Interaction and feedback (IF): Experts should review how the application allows deaf-mute users to interact with the platform and provide feedback. This includes evaluating communication features, user feedback mechanisms, and ease of content sharing.

e) Support and additional resources (SAR): They should assess whether the application provides supplementary resources, such as links to support websites, counseling services, or relevant information for the deaf-mute community. They should also consider if the application offers real-time support options.

The expert validation of the mobile application reveals a generally positive assessment, with specific areas of focus. In AU, the experts provided an average rating of 87, emphasizing the importance of compliance with accessibility standards and intuitive navigation for deaf-mute users. The ECC category received an average rating of 83, indicating that the educational content quality and support for SL communication need some improvements. VDM scored an average of 86, suggesting a strong emphasis on visual design, legibility, and multimedia accessibility; IF received a lower average rating of 79, highlighting the need for better interaction and user feedback mechanisms. SAR scored an average of 85, reflecting the importance of providing supplementary resources and real-time support options for the deaf-mute community. Overall, the experts' validation underscores the significance of a holistic approach that ensures both accessibility and content quality for this user group while also improving user interaction and feedback features (refer to Table 4).

Table 4. Expert validation

C	Experts										Mean
	1	2	3	4	5	6	7	8	9	10	
AU	90	90	80	90	80	80	90	90	90	90	87
ECC	80	80	80	90	80	80	90	80	80	90	83
VDM	90	80	90	80	90	90	90	90	80	80	86
IF	80	90	90	70	80	80	70	80	70	80	79
SAR	80	90	90	90	90	80	90	80	80	80	85

4.5 Proposed model

The model proposed in this study aims to comprehensively understand the distinctive traits of deaf-mute individuals and address their particular requirements.

The study delves into a profound comprehension of the deaf-mute community's encounters and interactions with their surroundings. It scrutinizes the common impediments they encounter, whether in education or society, and investigates feasible technological solutions to overcome these barriers. Thus, this study aims to design mobile apps that cater not only to the accessibility of individuals with speech and hearing impairments but also adapt to their requirements to promote active participation in society and educational settings. The utilization of mobile technology provides an advantageous tool for inclusion and equal opportunities. This paper discusses diverse aspects of mobile app design, including user interface and other functionalities to benefit the deaf and mute population. Furthermore, we take accessibility guidelines into account and introduce novel solutions to ensure that the apps are user-friendly and intuitive for individuals who experience hearing impairments (see Figure 9).

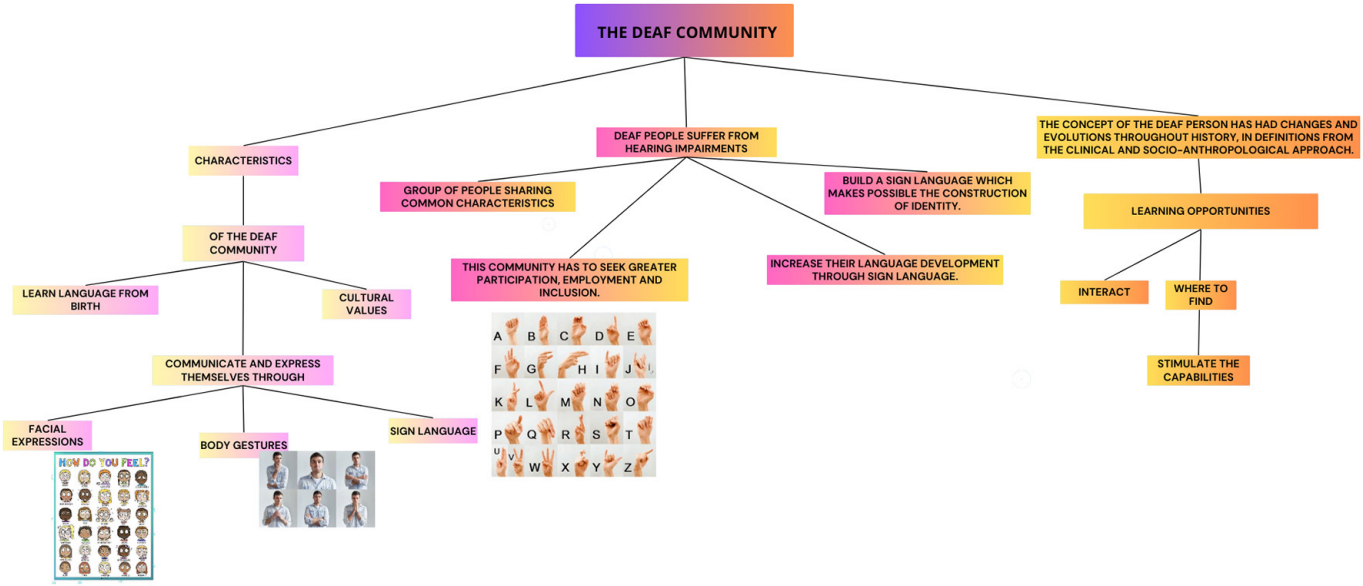

Fig. 9. Proposed model

5 CONCLUSION

Based on the interviews conducted, it is evident that there is a pressing need to prioritize accessibility features, such as subtitles, SL integration, and user customization in mobile applications. Additionally, tailored educational content and specific communication tools are required to support the academic and social development of these students. The involvement of parents in the design process is crucial for creating more inclusive and effective mobile applications. These findings underscore the importance of improving mobile application design to better serve the needs of students with deaf mute disabilities. Also, the user satisfaction survey for the mobile application designed for deaf-mute students reflects a generally positive reception, with most users expressing satisfaction. However, the need for targeted improvements in the relevance of educational content is evident, emphasizing the importance of aligning the application more closely with user expectations and needs. A limitation identified in the research is the lack of support and commitment from the educational authorities in the institutions where deaf-mute students' study.

This hinders the optimal implementation and development of the mobile application designed for these students. As a future endeavor, it is suggested that the research take a multidisciplinary approach, involving additional professionals such as psychologists, tutors, and other specialists to comprehensively address the educational and emotional needs of students with hearing and speech disabilities. This could lead to a more holistic and effective solution to enhance their educational and social experience.

6 ACKNOWLEDGMENT

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