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# S3L: TOWARDS A MOBILE-BASED SOLUTION FOR ENHANCING SIGN LANGUAGE COMMUNICATION BETWEEN PARENTS AND CHILDREN WITH HEARING IMPAIRMENT

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**Abstract:**

Parents of children with hearing impairment often face communication challenges due to limited access to flexible, culturally relevant, and user-friendly sign language learning tools. This study aims to design, develop, and evaluate S3L, a mobile application created to support parents in acquiring essential sign language skills for improved daily interaction with their children. Guided by a User-Centered Design (UCD) approach, the research was conducted in four phases: (1) exploring communication challenges; (2) defining application requirements and learning features; (3) application design and development; and (4) conducting a summative usability evaluation. Findings indicate that S3L is easy to learn and navigate, with users particularly valuing its clean interface, video demonstrations, and modular learning structure. However, several usability issues were identified, including scrolling limitations, repeated logins, and a limited vocabulary set, as areas for enhancement. Overall, S3L provides a practical, accessible, and self-paced platform that supports more inclusive parent–child communication, offering the UCD-driven, Malaysian-context mobile solutions tailored specifically for families learning sign language.

**Keywords:**

Sign Language, Mobile Application, User-Centered Design, Deaf Communication, Multimedia Learning, Inclusive Technology

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## Introduction

Sign language is a natural and fully developed form of communication that relies on hand movements, facial expressions, and body positioning to convey meaning. Like spoken languages, sign languages evolve organically within communities, with more than 300 distinct signed languages identified worldwide. In Malaysia, early intervention in sign language acquisition is particularly critical, given the increasing number of children diagnosed with hearing impairments. According to the Malaysian Ministry of Health, 987 children were identified with hearing loss through the Universal Child Hearing Screening Programme in 2023, highlighting the growing need for effective communication support within families (Harun, 2024).

Despite this need, communication between hearing parents and children with hearing impairments remains a significant challenge. Many parents have limited prior exposure to sign language and struggle to acquire sufficient skills to support everyday interaction. This communication gap can result in social exclusion within the family environment, emotional distress, and reduced parent–child bonding (Hauser et al., 2010; Lee et al., 2021). Existing sign language learning resources are often fragmented, academically oriented, or designed primarily for children or formal educational settings, making them less suitable for parents who require flexible, practical, and contextually relevant learning tools.

Time constraints further compound these challenges, particularly for working parents who are unable to attend conventional face-to-face or scheduled online sign language classes. As a result, there is a need for learning solutions that support self-paced, accessible, and sustained engagement with sign language learning in everyday contexts. Mobile technologies offer considerable potential in this regard, as they enable learning to occur across time and place while accommodating diverse user needs and digital capabilities.

In response to these challenges, this study presents the design, development, and evaluation of S3L, a mobile application intended to support parents in acquiring essential sign language skills for improved communication with their children who have hearing impairments. Guided by a User-Centered Design (UCD) approach, the study aims to: (1) identify the communication challenges and learning needs of parents; (2) translate these needs into application requirements and learning features; and (3) evaluate the usability of the developed application. By focusing on a Malaysian context and a parent-oriented learning perspective, this study seeks to contribute a practical, culturally relevant mobile solution that supports inclusive parent–child communication through accessible sign language learning.

## Literature Review

Sign language functions as a primary linguistic system for individuals with hearing impairments and plays a critical role in facilitating communication, cognitive development, and social participation within the family context. For children with hearing impairments, early and consistent access to sign language is closely associated with stronger language acquisition and emotional bonding with caregivers (Hauser et al., 2010). However, in many hearing families, parents possess limited proficiency in sign language, creating persistent communication barriers that affect daily interaction and relationship development (Lee et al., 2021). Within the Malaysian context, these challenges are further intensified by the limited availability of parent-oriented, culturally relevant learning resources. As a result, there is an increasing need to examine how accessible learning tools, particularly mobile-based solutions,

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can support parents in developing practical sign language skills that are applicable to everyday communication scenarios.

Learning sign language as a parent is not without its challenges. Many parents report having limited exposure to sign language prior to their child's diagnosis, and opportunities for formal training are often scarce (DeForte et al., 2020). For working parents, time constraints can make consistent learning especially difficult (Lee et al., 2022). On top of these practical challenges, the scarcity of culturally and linguistically relevant materials further complicates the learning process (Chuan & Guardino, 2016). These barriers can widen the communication gap within the family unit, potentially impacting both the child's language development and emotional well-being (Hauser et al., 2010).

In response to these challenges, digital platforms have begun to offer new possibilities for supporting sign language acquisition. Applications such as SmartSignPlay and Sign4Baby provide video-based lessons and interactive features aimed largely at children (Chuan & Guardino, 2016; Weaver, 2011.). However, tools designed specifically for parents remain limited. Many of these existing platforms are created for educational contexts and often lack the flexibility, personalisation, and situational relevance that parents need in everyday communication scenarios (David et al., 2023). Research by Hashim (2020) demonstrates that sign language-integrated e-learning environments enhance usability and academic performance among deaf learners. Still, adapting these tools to better serve family-oriented learning environments remains a key challenge.

The growing interest in mobile learning technologies offers promising pathways to address these gaps. Mobile platforms provide flexible, on-the-go access that fits well with the schedules and learning preferences of adult users. According to Mayer's (2005), the Cognitive Theory of Multimedia Learning, combining verbal and visual elements enhances understanding a principle particularly relevant to sign language, which is inherently visual. Similarly, Paivio's (1990) Dual-Coding Theory highlights how engaging both verbal and non-verbal systems can strengthen memory and learning. When mobile apps integrate video demonstrations, textual prompts, and audio instructions, they can accommodate different learning styles while increasing user engagement and retention (Zhao, 2024).

To ensure such tools are truly effective, they must be designed with users at the centre. Applying the UCD approach allows developers to create solutions that reflect the actual needs, preferences, and digital capabilities of parents (Tawil, 2025). Design elements such as clean interfaces, pastel colour palettes, large icons, and intuitive navigation are particularly helpful for users with limited digital literacy (Mayer, 2005; Nielsen, 2024). Moreover, motivational features like progress tracking, badges, and feedback systems can boost user engagement and make the learning experience more rewarding (Hellín et al., 2023). Delivering content in both Bahasa Melayu and English can also improve accessibility and relevance for Malaysian users (Lee et al., 2021).

Despite increasing scholarly attention to sign language education and digital learning technologies, several gaps remain unresolved. Existing sign language applications and learning platforms predominantly target children, students, or formal educational settings, offering limited support for parents who serve as primary communication partners in everyday family interactions (Weaver & Starner, 2011; Chuan & Guardino, 2016). From a design perspective,

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although multimedia learning theories and user-centred design principles are frequently cited, many mobile sign language applications lack clear evidence of how these frameworks are operationalised in practice, particularly within family-oriented learning contexts (David et al., 2023; Hashim & Tasir, 2020). Additionally, most available solutions are developed within Western or generic contexts, with insufficient cultural and linguistic adaptation to meet the needs of Malaysian families of children with hearing impairments (Lee et al., 2021; Tawil et al., 2025). These gaps highlight the need for a parent-oriented, mobile-first solution that integrates multimedia learning principles and user-centred design within a culturally localised context. In response, this study introduces S3L, a mobile application designed to support parents in acquiring practical sign language skills through an accessible, self-paced, and contextually relevant learning environment.

## Methodology

The app was developed in four structured stages of understanding the communication challenges and user requirements, defining application requirements and learning features, application design and development and usability testing and evaluation. This research implemented the User-Centered Design (UCD) initiative to make the mobile application conform to parent needs of children with hearing impairments in communication problems. A similar approach has been successfully applied in developing mobile applications for children with autism, particularly effective in addressing the specific needs of targeted user groups within small-scale interventions (Saidin et al., 2024).

### *Phase 1: Understanding the Communication Challenges and User Requirements*

In the first stage of the study, a qualitative research approach was employed to gather in-depth, contextual insights from key stakeholders involved in the care and communication development of children with hearing impairments, namely, parents, special education teachers, and members of the Deaf Community. The objective was to understand their lived experiences, communication challenges, and expectations for a learning platform that could help bridge the communication gap. Data were collected through semi-structured interviews and online questionnaires. The interviews explored participants' current sign language knowledge, learning obstacles, past experiences with sign language resources, and preferences for digital learning tools. The questionnaires complemented this by capturing demographic information, digital literacy levels, and preferred learning styles (e.g., visual, auditory, or interactive).

Five participants consist of two parents, two special education teachers and a teenager (undergraduate students) which has hearing impair sibling were involved in this phase. The finding demonstrated that there are three major challenges experienced by caregivers and parents. To begin with, there are no well-organized, user-friendly learning tools specifically designed for families who are new to sign language. Most existing resources are either too academic, focused only on children, or scattered across different platforms, making them hard for parents to access. Secondly, parents did not have time to study in a traditional setting, i.e., a face-to-face classroom or a synchronous online tutorial. This necessitated the demand of flexible self-paced mobile learning environments where people could access them any time and any place. Thirdly, the information indicated that some family members (who are normal) have low awareness and lack of confidence to use it during interacting with their children. Such communication obstacles usually led to emotional separation, frustrations, and lack of connections of the family members. Additionally, a persona was developed to represent the

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target audience, parents of children with hearing impairments that highlighting their goals, motivations, behaviours, and pain points relevant to this phase of the study (Figure 1).


**Figure 1: Persona of Parent with Hearing Impairment's Children**

***Phase 2: Defining Application Requirements and Learning Features***

In the second phase, the project focused on translating user needs into a structured set of functional and non-functional requirements to guide the development of the mobile application. This was done by analysing responses from interviews, surveys, and user personas created earlier which features would be most helpful and accessible for parents learning sign language, especially those with little or no prior experience. The application requirement was laid out in Table 1.

**Table 1: Application Requirements for Sign Language Learning Mobile App**

| ID | Requirement | Description | Rationale |
|---|---|---|---|
| **FR01** | Sign Language Video Library | Provide a variety of video-based sign language lessons, like greetings and emotions. | Visual demonstrations support accurate hand- and facial-gesture recognition which are critical for sign-language learners (Emmorey et al., 2009; Berrezueta-Guzman et al., 2025; Ekhsan et al., 2022). |
| **FR02** | Categorized lessons | Organise content into themed modules such as daily activities, feelings, and needs. | Thematic categorisation helps users focus on relevant vocabulary and encourages contextual learning." (Yin, 2022) |
| **FR03** | Interactive practice module | Include quizzes activities to test user knowledge | Active engagement promotes better retention and allows users to self-assess their learning progress (Rossi et al., 2021) |
| **FR04** | Progress tracker | Visual dashboard to show completed lessons, and badges | Helps maintain user motivation and provides a sense of achievement through visible progress markers (Hellín et al., 2023) |

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| **NFR01** | Minimalist interface design | Clean, simple UI with pastel tones and large, clear icons for easy navigation | Reduces cognitive load and supports users with lower digital literacy, particularly parents unfamiliar with tech (Tawil, 2025; Mayer, 2005). |
| **NFR02** | Lesson segmentation | Divide lessons into short, manageable modules to avoid overwhelming users. | Follows Mayer's segmenting principle, allowing users to control pacing and absorb information more effectively (Mayer, 2005) |

Each of the design choices was constantly affirmed with the initial user personality investigated earlier. The result herein would be a well-represented specification of the functionality of all the apps, the user interface, and content provision methods that would directly influence the development of the high-fidelity prototype in the next phase.

***Phase 3: Application Design and Development***

In the third phase, the mobile application was developed with the integration of the design preference according to the user persona during the first phase and the application's requirements that were made in the second phase. The process of development took around two months, through an iterative process of planning, designing, and prototyping using Adalo Software Development application. Adalo is a low/no-code app development system that has been integrated and used to deploy apps with quick speed that also a cross platform which suitable for both android and iPhone (Saidin, 2024). The development was focusing on several stages that consisted of Interface design, the core module, technical development and engagement features that will be explained in detail in the following section.

***Application Interface Design***

The User Interface (UI) development focused on clarity, simplicity, and seamless interaction. The visual design followed a minimalistic and clean layout, avoiding unnecessary elements that could overwhelm users. Big icons, clear fonts, and pastel colour schemes were selected for optimal readability and usability (figure 2). Special attention was given to ensuring smooth page-to-page navigation, reducing cognitive load and creating a frictionless user experience, which is essential for first-time users or those with limited digital experience.

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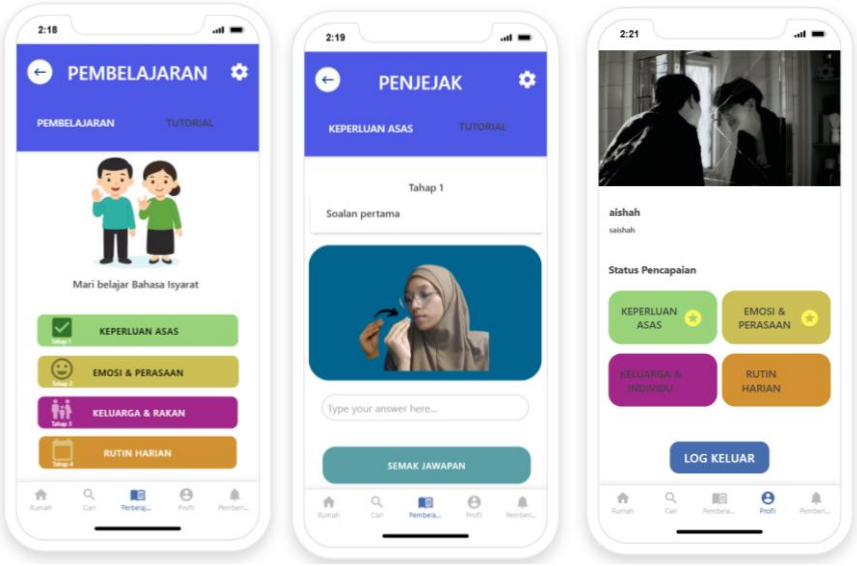


**Figure 2: Interface of Core Module**

***Core Module***

The core module is the essential component that provides the fundamental functionality or structure of the mobile application. The application was divided into three main modules, which are the Learn Signs, Practice and Quiz and User Profile & Tracker in which inspired this mobile application name S3L (sign language with 3 modules). Each module is meant to cater to different functions with embedded multimedia elements that would enrich the learning experience (Table 2).

**Table 2: Core module of Sign Language Learning Mobile Application**

| Module | Function | Features |
|---|---|---|
| **Learn Signs** | Functions as online sign language library. It helps with visual learning and development of a base vocabulary in line with everyday communication as well. | • Video demonstrations for each sign.<br>• Text descriptions in Bahasa Malaysia.<br>• Categorized themes: Basic needs, emotions &, family & friends and daily routine. |
| **Practice and quiz** | Provides interactive space for self-assessment and reinforcement. It helps to encourage active recall and self-paced learning through typing responses, promoting deeper memorization and understanding. | • Users are shown an image and must type in the correct meaning.<br>• Feedback is provided after submission to confirm if correct or incorrect input. |
| **User Profile & Tracker** | Allows users to monitor their learning progress. It encourages users to learn more by giving them concrete | • View completed lessons.<br>• Track quiz participation. |

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| | evidence of improvement and strengthening their determination to learn sign language. | • Visual indicators such as lesson status and learning milestones. |

The application's content is organised into small, thematic learning modules. Each module follows a consistent structure consisting of sign language demonstrations through videos, accompanied by brief text descriptions in Bahasa Malaysia. The materials are delivered in a combination of text, images, and videos to cater to different learning styles. This visual and textual integration enhances comprehension, especially for users with limited prior knowledge of sign language. The design aligns with Mayer's Multimedia Learning Theory, incorporating principles such as dual coding (video + text) and segmenting (breaking information into manageable chunks for better understanding) (Mayer, 2005). The choice of Bahasa Malaysia ensures accessibility for local users, particularly parents who are more comfortable learning in their native language. While the current version does not yet include voice narration or English translation, its structure allows for future enhancements. Planned improvements include bilingual support and audio narration, which will help make the application more inclusive and suitable for a wider audience.

***Technical Development Consideration***

For this project, Adalo Software was selected as the development platform due to its cross-platform capabilities, enabling rapid deployment across both iOS and Android devices without the need for separate coding environments. Adalo's intuitive no-code interface allowed for efficient prototyping, real-time previews, and swift iteration, which is ideal for small-scope, user-focused educational applications. The decision was aligned to ensure accessibility and ease of use for developers and end users alike, particularly parents who may not be technologically savvy. A key feature incorporated during this stage was a basic login system. This functionality allows each user to create a personalised account and profile, offering a more tailored experience. With individual profiles, users can track their learning progress over time, which not only enhances engagement but also supports self-paced learning.

Additionally, S3L mobile application also underwent testing and debugging for each module to identify technical issues, functionality glitches or visual inconsistencies from time to time. This was done to ensure error-free, stability and responsiveness when it is used by the intended user. This thorough process helped to ensure the app is ready for real-world use and able to provide a good user experience.

***Engagement Features***

To encourage users to stay motivated throughout the learning process, the application includes several user-friendly and supportive features. (1) Star badges and visual rewards are provided to celebrate learning achievements and add a sense of excitement. (2) The interface features large, easy-to-recognise icons to ensure smooth navigation, even for first-time users. (3) Positive feedback messages are displayed after correct quiz answers to help boost user confidence. (4) Lastly, users have the freedom to repeat any lesson or quiz at their own pace, without pressure. This approach is designed carefully, especially to engage the user during learning. Refer Figure 3, for the engagement features.

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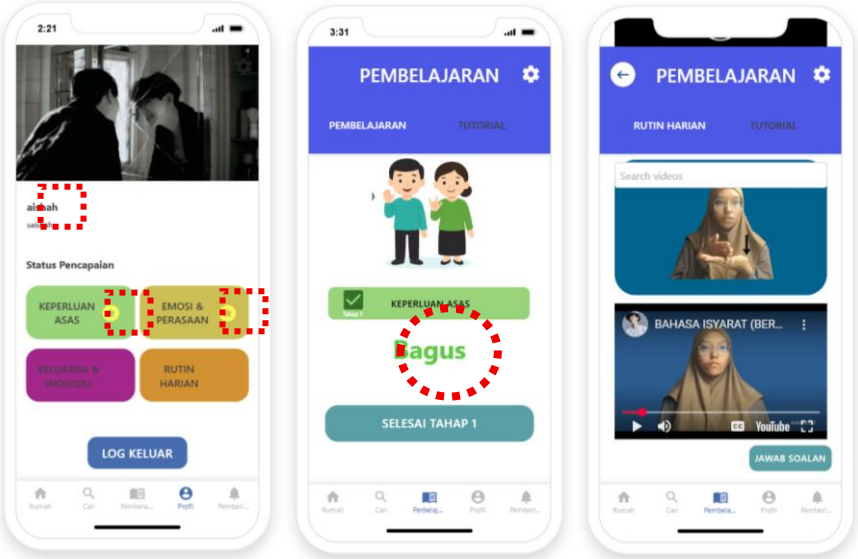


**Figure 3: Interface of Engagement Features**

***Phase 4: Usability Testing and Evaluation***

The final phase of this project involved a summative evaluation to assess the usability of the sign language mobile application. This stage aimed to determine how effectively the target users (parents of children with hearing impairments) could interact with the app, learn from it, and find it useful in their daily communication routines. Following Nielsen's (2024) recommendation for early-stage usability testing, a qualitative approach was adopted, as it has been shown that valuable insights can be gathered from as few participants. The respondents were recruited through informal networks, selected based on their willingness to engage with the prototype and provide detailed feedback.

The open-ended interviews were conducted online via chat platforms to provide participants with greater flexibility and comfort (Figure 4). Before each session, participants were instructed to explore the application independently using their own smartphones. During the interviews, they answered all the questions, reflected on their experience, shared detailed feedback, and identified any challenges they encountered. All responses were documented and analysed using a simple thematic analysis approach, which involved initial familiarisation with the data, generating preliminary codes, organising these codes into broader themes, and reviewing the themes for coherence. To strengthen the trustworthiness of the findings, two additional research team members independently reviewed the coded data and themes, followed by a triangulation discussion to resolve discrepancies and reach agreement. This collaborative verification helped ensure that the insights generated were credible and accurately represented the participants' perspectives, ultimately guiding meaningful improvements to the application and ensuring it better meets the needs of its intended users.

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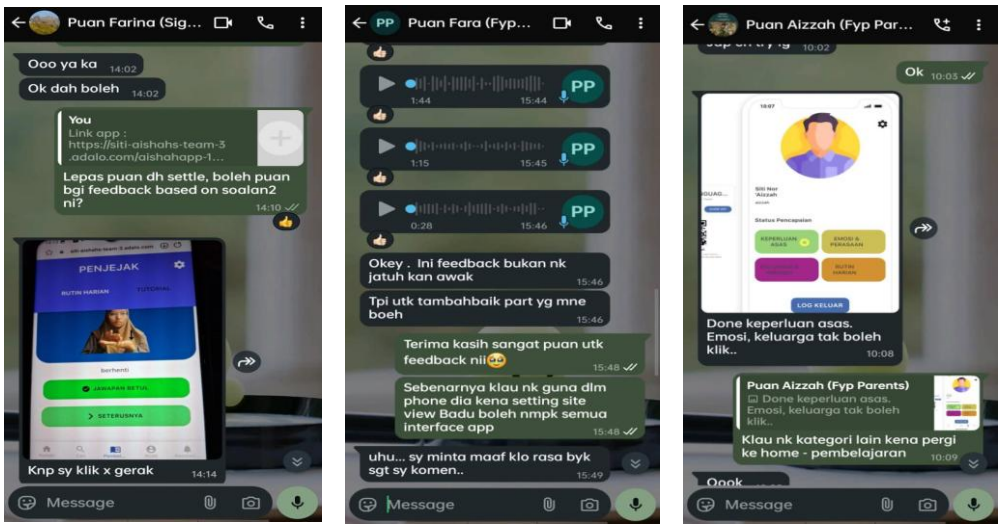


**Figure 4: Evaluation Exercise of S3L**

## Findings and Discussions

The usability evaluation findings were organised into five themes: ease of use, ease of learning, usability and navigation, satisfaction, and overall impression. Participants (identified as A, B, C, and D) were mothers aged between 39 and 52 years who had children with hearing impairments and possessed basic sign language knowledge acquired through self-learning or school exposure (Table 3).

**Table 3: Evaluation Phase – Finding**

| Criteria | Finding |
|---|---|
| **Age and User Background** | The age of the participants was between 39-52 years. They were all mothers of children with hearing impairment who had basic knowledge of sign language, either acquired in self-learning or school-induced learning. |
| **Ease of use** | Most of the participants (A, C, and D) did not find the app challenging to use because of its simple structure and usable design. Nonetheless, Participant B claimed having issues with navigating on mobile, and scrolling and accessing the quiz.<br><br>This pattern suggests that the minimalist interface and straightforward navigation successfully supported learnability for first-time users, aligning with Nielsen's usability heuristics related to simplicity and ease of learning. From a User-Centered Design perspective, the positive responses indicate that key design decisions were effective in reducing cognitive load for the majority of users. At the same time, the difficulties reported by Participant B highlight how usability is influenced not only by visual simplicity but also by mobile-specific interaction constraints, such as screen size and gesture-based navigation. |
| **Ease of learning** | The learning process was self-explanatory among the participants, and this was enhanced by the use of videos and |

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| | images. Nevertheless, the Participants A and C suggested that written instructions to first-time users should be added to better onboard them.<br><br>The strong reliance on video-based learning reflects the visual nature of sign language and supports the principles of Multimedia Learning Theory and Dual-Coding Theory, which said that combining visual and verbal elements enhances comprehension and recall. In this context, video demonstrations functioned as the primary instructional mechanism rather than supplementary material, suggesting that effective sign language learning depends heavily on accurate visual modelling. The request for written instructions indicates a need to support initial mental model formation, particularly for users with lower digital confidence. |
| **Usability and Navigation** | The visual design was well understood by their users. Participants B and C mentioned that they observed the slightest limitations, including several loggings into new levels, incorrect quiz authentication and only a small word count. These affected the general traffic to some users.<br><br>These findings reveal a gap between theoretically sound design principles and their technical implementation. While the application was developed based on user-centred and multimedia learning principles, the reported issues demonstrate how system-level constraints can hinder user experience. This suggests that usability in mobile learning applications is shaped not only by instructional design but also by backend logic and interaction continuity, reinforcing the importance of iterative testing in real-use conditions. |
| **Satisfaction** | Participants A, D and C were the three participants out of four that were satisfied with the application, and they found utility in communicating with their children through the app. Participant B was less satisfied and said that it was not very convenient to use the site on a mobile device and provided that the variety of content should be increased.<br><br>Participant satisfaction appears to be closely linked to perceived usefulness and ease of access, both of which are central to user engagement in mobile learning environments. The positive responses suggest that the application meets an immediate need for flexible, home-based sign language learning. However, the dissatisfaction expressed by Participant B indicates that engagement is sensitive to usability disruptions and content depth, highlighting areas that may affect sustained motivation over time. |
| **Overall Impression** | The app was viewed as useful and efficacious, particularly among the parents seeking to find flexible, at-home learning |

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| | alternatives. Each one of the participants is enthusiastic of the possibility of using the app in future and being comfortable with recommending the app particularly after recommended improvements which were not covered by the app.<br><br>This overall positive impression suggests early acceptability of the application as an entry-level learning tool rather than evidence of long-term learning effectiveness. From an analytic perspective, the findings indicate that perceived usefulness and accessibility drive initial adoption, while sustained use is likely to depend on refinements related to responsiveness, instructional support, and content expansion. These insights reinforce the importance of aligning usability, learning theory, and technical reliability in parent-oriented mobile learning applications |

The sign language mobile application evaluation helped to identify some important opportunities and drawbacks of the mobile application effectiveness and its acceptance by the users. The majority of participants valued the cleanness of this app, the support of video, and the easy structure, due to which the app was easier to learn and navigate, particularly by customers who already knew sign language. The modularity aspect of the content used in the application and graphical representations stimulated fast recollection and engagement and ability, particularly when used in larger screens such as the laptop. However, one of them suggested that it would be necessary to focus on better responsive design and functionality, including scroll ability and consistent quiz feedback. The other recommendations made included the inclusion of written manuals or tutorials on using this application especially for first-time user.

Generally, all participants were pleased with the app and its potential to facilitate effective communication between parents and hearing-impaired children on a daily basis. Their response contains important information regarding the usefulness of the app as an entry-level learning tool, as well as areas for improvement and enhancement.

**Limitation**

Given the hard-to-reach nature of deaf users and their guardians, as well as the ethical and interpretation challenges involved, this study adopted a very small sample (N = 4) for usability testing (Nielsen, 2024). While this limited number of participants may affect the generalizability of the findings, the approach is consistent with established usability research emphasising the value of small-N evaluations in accessibility contexts. Furthermore, the online interviews were performed through the Darwin Software chat interface, which has successfully gathered immediate input, however limits the opportunities to observe in-depth natural user interactions. Consequently, the assessment primarily focused on short-term impressions rather than long-term retention, engagement, or learning outcomes. These methodological constraints should be considered when interpreting the results and will inform subsequent stages of application refinement and future development.

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## Conclusion

The development of the sign language mobile application is an important step in enhancing communication between parents and children with hearing impairment. This application not only satisfies the real practical needs of such families, the application also provides the ability for parents to be more involved in the learning of their child. This combination of properly selected multimedia (visual, animations, and video demonstrations) based on the Multimedia Principles and Dual-Coding Theory formulated by Mayer (2005) and implemented by Paivio (1990) can make the process of learning enjoyable and reachable, as the application can also be used by users without technical education or experience.

The results of the summative evaluation of four participants pointed to distinguishing several main points: (1) Ease of Use - most individuals stated that the app was user-friendly and straightforward, especially on bigger screens, and required little to no instructions (Nielsen, 2012). (2) Ease of learning - the application of short sets of vocabulary accompanied by video-modelling was stated to provide an efficient learning support that facilitated a full understanding and recall by the user, particularly to those who were already exposed to sign language (3) Usability Problems, there were some identified challenges such as navigating the application on a mobile device, having to log out to open the next level and low vocabulary. These are the areas that propose that design should be improved in order to make the app more open to more people and useful in the long term. (4) User Satisfaction - despite the usability issues identified, participants expressed overall satisfaction with the app, indicated they would consider using it in the future, and reported being willing to recommend it to others in similar situations.

In short, a mobile sign language application can be a potentially inclusive digital platform that can be used to break the communication barrier between caretakers and deaf children. Although the preliminary assessment indicates a positive evaluation in regards with usability, satisfaction and facilitation of learning, there is a need to improve the shortcomings that have been felt with this project. The challenges that could be addressed in the future include expanding the vocabulary database, improving the mobile experience, and running longer tests with people with hearing impairments and their guardians.

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