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Research Article

Consensus on Criteria for Selection of Sign Language Mobile Apps: A Delphi Study

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ABSTRACT

In the rapidly evolving digital learning landscape, sign language mobile apps are vital in advancing sign language teaching. However, ensuring the quality of these apps remains a critical challenge. To address this gap, this study employs the fuzzy Delphi technique to establish a robust set of criteria for evaluating the quality of sign language mobile apps. By leveraging the collective wisdom and expertise of a panel of experts, the fuzzy Delphi technique facilitates a structured process for achieving consensus on the essential factors contributing to evaluating sign language mobile apps. Through rigorous rounds of iterative feedback and analysis, the study identifies a comprehensive list of reliable criteria encompassing various dimensions, including functionality, usability, accessibility, and pedagogical effectiveness. The criteria established through this method serve as a valuable resource for developers, educators, and clients in selecting and developing top-notch sign language mobile apps. Developers can use the criteria as a guide during the design and development stages, ensuring that their apps meet the highest quality and user experience standards. Educators can rely on the criteria as a checklist for evaluating and selecting appropriate apps that align with their teaching objectives and cater to the diverse learning needs of their students. Clients, such as educational institutions or individuals seeking sign language learning resources, can make informed decisions by referring to the established criteria, promoting the adoption of clear and impactful sign language mobile apps. This study emphasizes the significance of applying the fuzzy Delphi method in the context of sign language mobile app assessment. Involving experts from relevant fields ensures that the established criteria capture the multifaceted nature of compelling sign language learning experiences. Developing a comprehensive and reliable set of criteria contributes to improving existing apps and encourages innovation in creating new apps that better serve the needs of sign language learners. Overall, this research extends the knowledge base of sign language teaching in the digital age by providing a robust framework for assessing the quality of sign language mobile apps. The findings of this study empower stakeholders in the education and technology sectors to make informed decisions, fostering the advancement of sign language teaching and promoting inclusivity in digital learning environments.

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1. INTRODUCTION

Sign language is a visual language that allows deaf and hard-of-hearing individuals to communicate effectively. It plays a crucial role in fostering inclusivity, promoting accessibility, and preserving cultural identity within the deaf community [1]. Learning sign language provides many advantages for both hearing children and adults. Equipping with sign language helps people become more apprehensive of and sensitive to the needs of individuals with hearing disabilities. Its key perks include improving the learner's cognitive ability, enthusiasm to study in formal and informal environments, independence and confidence, and the development of personalized learning, which assists low-performing students in attaining its objectives [2]. Sign language has experienced a remarkable evolution in the realm of technology, leading to breakthroughs in the form of mobile apps [3]. These apps have revolutionized accessibility and learning opportunities for the deaf community. With the advancement of mobile technology, sign language apps have emerged as powerful tools for learning, practising, and improving signing skills. According to a recent study by [4], mobile apps provide a convenient and interactive platform for users to access sign language resources anytime, anywhere. These apps offer features such as video tutorials, interactive lessons, quizzes, and extensive sign language dictionaries, catering to learners of all levels. The study emphasizes that sign language mobile apps have the potential to enhance self-directed learning and facilitate communication between deaf individuals and the hearing community. Mobile apps have brought numerous advantages to sign language, offering a range of criteria that need to be considered for their effectiveness. Several mobile applications for studying specific courses using sign language have been developed over time to make learning more convenient; however, before these applications are made available to end users, various tests should be conducted. They are needed to ensure that it is of adequate standard, is stable, and fulfils the specified criteria or requirements [5]. However, a few existing sign language mobile learning applications [6] are often too limited and inadequate for efficient sign language learning. Therefore, an imperative need exists for automated and efficient assessment of mobile applications for sign language where users still heavily trust either application store ratings or the Content rated by the application developer. While looking at academic literature, it turned out that most sign language mobile apps have been mainly assessed by either conducting an in-house testing and evaluation or running these apps in different experimentations set by their developers and authors. None of these apps had undergone a quality assessment in term of standardized approach except for one study by [7] where authors performed quality assessment on mobile apps for sign language using Mobile Apps Rating Scale (MARS). However, despite the potential of MARS as an assessment tool which can be used for mobile apps, especially those related to sign language, it still has its own shortcoming which does not make it by itself at least the best tool for Sign language mobile apps. Therefore, in this research we are bridging this gap of MARS assessment by infusing its criteria with ones from the academic literature linked to mobile apps content, and thereby creating a unified assessment methodology where not only subjective criteria reflecting user perspective are only considered, but also introducing a content, functions and design criteria which will be as important for consideration while assessing sign language mobile apps, and measuring their importance weights and its impact on the assessment.

2. LITERATURE REVIEW

As the criteria selection is a novel and innovative topic, creating a consensus on criteria for sign language mobile apps using the Delphi method is proposed, as it is an effective method for obtaining a consensus among experts in any field of study. The fuzzy Delphi method allows for the aggregation of expert opinions and knowledge. Collecting and synthesizing inputs from a diverse group of experts facilitates the identification of shared perspectives and areas of agreement, leading to more informed decision-making [8]. There are two different criteria collected. Firstly, the MARS criteria were used in the mobile app assessment, and the collected criteria through a literature review. The collected criteria are categorized as primary and sub-criteria, similarly mentioned in Table 1, and these criteria are then standardized using Fuzzy Delphi with the aid of experts. Fuzzy Delphi is performed to validate the list of criteria by experts related to sign language mobile app development. A finalized set of criteria is established at the end of the process, making way for the criteria weighting.

Table 1: List of Main and Sub Criteria

Main Criteria	Sub Criteria
Design	Operating System, Customization, Help Support, Developer Feedback, and Resizing
Content	Number of Dictionaries, Storing New Words, Offline and Online Usage, Image Dictionary, and Searching for Content Online.
Recognition	Gesture Recognition and Sensor Recognition
Translation	Sound, Word, Sound to Sign, Text to Sign, and Sign to Text

Enabling feature	Bluetooth, Searching Options for Words, Game Play, Fingerspelling Keyboard, Advanced Technology, 3D, Animations and A.R.
Cost	Free App

2.1. PANEL OF EXPERT COMPOSITION

Following the completion of expert identification, a group of experts for the case study is chosen. This step requires at least four specialists [9]. All former experts are contacted through email to determine their availability and willingness to participate on the panel as potential experts. Lastly, only 17 responses on behalf of the expert's opinion were received. Author [10] mentions that the Delphi method's expert panel size varies, but with a homogeneous group of experts, good results can be obtained even with small panels of 10–15 people. Therefore, we have 17 content experts to collect the respective feedback. In this study, 17 experts participated in fuzzy Delphi analysis; their selection details are below. Among the experts, four respondents were lecturers, four was associate professors, and the rest was software requirement analyst, agile coach, government employee, app developer, R.P.S. engineer, PhD student and others. They are from the various international organization such as Dell Lead, Khon Kaen University, Government Engineering College, University of Indonesia, Prime University, ExxonMobil, Government Sector, Educational-University, Robert Bosch, American International University-Bangladesh, RCCIIT Kolkata India, American International University-Bangladesh (AIUB), University of Florida, KPMG Philippines, A game company, and T.I.P. Manila Philippines. The years of working experience were one of the questions that the expert asked. This ensures that they have experience in their respective field of study. Five of the 17 experts have more than 15 years of experience, three have one to two years of experience, five have three to five years of experience, two have six to ten years of experience, and two have 10-15 years of experience in their respective fields.

2.2. DELPHI QUESTIONNAIRES

The expert questionnaire can be developed in different ways, such as through (1) literature review and (2) interviews. The development of questionnaire items can be done based on a literature review, pilot studies, and experiences [11]. The researchers used the literature review and Mobile App Rating Scale (MARS) to develop the research questionnaire for the Fuzzy Delphi method. Creating the expert questionnaire was a down-to-the-last detail and time-consuming process. The questionnaire was developed using Google Forms and divided into three sections: Part A, Part B, and Part C. Part A requires personal information such as name, position and working experience of experts. This part uses long text and a checklist menu where experts can write their position and choose the working experiences from given choices. Part B is for rating the main criteria consisting of six criteria: design, Content, recognition, translation, enabling feature and cost, and lastly, Part C is for the six sub-criteria. Part B and Part C are created based on the multiple-choice grid with a Likert scale of Very Important, Important, Neutral, Low Important and Not Important. After adapting the questionnaire from the literature, it was given to the supervisor for feedback. Then, modifications were made to the questionnaire based on their feedback. The questionnaire was then developed in Google Forms.

2.3. DELPHI ROUNDS

Fuzzy Delphi was carried out only once with (n=17) experts. The final set of questionnaires was ready and sent on December 8th 2021. A checklist was created for respondents, and reminder emails were also sent to some experts who mis-looked the email. The final number of responses was 17, and all the data has been collected for further analysis. Researchers and practitioners have recognized the value of single-round Delphi processes in specific contexts. For example, in the study by [12], a single-round fuzzy Delphi process was used to evaluate scientific research proposals in a neutrosophic environment. The authors deemed a single round sufficient for gathering expert opinions and reaching a consensus within their decision-making context.

2.4. DATA ANALYSIS

To address the problems of criterion determination and standardisation, this approach is based on the classic Delphi method and fuzzy theories. For FDM, the iterative process is stabilised by use of fuzzy statistics or continuous mathematically explicit membership functions [13]. When evaluating sign language mobile apps, this method is useful for unifying criteria and assigning relevance levels to them. The eight stages of the FDM are as follows: identifying experts, creating an expert form, disseminating the form and collecting data, converting Likert scales to fuzzy sets, analysing the data and determining a threshold value, reaching a consensus among experts analysing the data, defuzzifying the data, and interpreting the results. In step 4 (Likert Scale Conversion into Fuzzy Set), we use the linguistic variable for five scales to convert all of the expert data we collected into triangular fuzzy numbers, as shown in the table below.

Table 2: Linguistic variable

Likert Scale	Linguistic Change Enable	Fuzzy Scale
1	Not at All Important	(0.0,0.0,0.2)
2	Not Important	(0.0,0.2,0.4)
3	Neutral	(0.2,0.4,0.6)
4	Important	(0.4,0.6,0.8)
5	Very Important; Agree	(0.6,0.8,1.0)

Step 5 (Data Analysis and Threshold Value) involves data analysis, which is conducted based on the triangular fuzzy numbers to acquire the threshold value. The threshold value must be equal to or less than 0.2 because it presents the first acceptance conditions [14]. The distance between two fuzzy numbers $m = (m_1, m_2, m_3)$ and $n = (n_1, n_2, n_3)$ can be computed using the vertex method as shown in the formula below.

$$d(\tilde{m}, \bar{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3$$

Expert consensus is determined in Step 6 (Data Analysis), and it must be larger than 75% per the second requirement. Step 7 (Defuzzification Process in Data Analysis) involves getting the fuzzy score by eliminating the uncertainty. To pass the final test, 'A' must be larger than or equal to the level of 0.5 found in the middle of the distribution [15]. Further, 'A' can be used to determine the opinion-based priority factor. The following equation can be used to implement the fuzzy 'A' score:

$$A = \left(\frac{1}{3}\right) X \ (m_1 + m_2 + m_3).$$

2.5. ETHICAL CONSIDERATIONS

Ethical considerations play a crucial role in implementing the fuzzy Delphi method. Researchers were mindful of several ethical aspects, such as informing about the study's purpose, procedures, and potential outcomes. Individual responses were kept confidential and not attributed to specific participants as this helps create a safe environment for honest and unbiased input.

3. RESULTS

Step 8's Fuzzy Score Value and Data Interpretation explains how to apply the acceptance and rejection criteria to the data collected by FDM. Experts agree on three criteria that must be met before an item is considered for disposal or preservation.

- For each experiment, experts agree on a score based on the triangle fuzzy numbers. For an item to be approved, its acceptance rate must be lower than or equal to 0.2 [14].
- The majority of the threshold must be larger than 75% [16] for the item to be considered.
-
- By consulting an expert and establishing a threshold to prevent insufficient division [15], pseudo-partition can be used to identify the importance of a factor within an item.

Table 3: Data Interpretation on Criteria

		Design	Content	Recognition	Translation	Enabling feature	Cost
1st condition	The value D of each item	0.19	0.14	0.21	0.19	0.15	0.17
	The value of d for all	0.174					
	Accept each item has d <=0.2	Accepted	Accepted	Rejected	Accepted	Accepted	Accepted
2nd condition	Percentage of Each Item (d ≤ 0.2)	88%	100%	88%	88%	59%	94%
	The overall percentage >=75%	86%					
	Accept each item has >=75%	Accepted	Accepted	Rejected	Accepted	Rejected	Accepted
3rd condition	Average of fuzzy numbers (expert response)	0.482 0.682 0.882	0.471 0.671 0.871	0.471 0.671 0.871	0.506 0.706 0.906	0.365 0.565 0.765	0.482 0.682 0.882
		m1 m2 m3	m1 m2 m3	m1 m2 m3	m1 m2 m3	m1 m2 m3	m1 m2 m3
	Average of fuzzy numbers	0.682	0.671	0.671	0.706	0.565	0.682
	Rank	2	4	4	1	6	3
	Accept each item has >=0.5	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

The results of the three conditions are shown in Table 3. The d value for the first criterion should be less than or equal to 0.20. The d value for Design (0.19), Content (0.14), Recognition (0.21), Translation (0.19), Enabling feature (0.15) and Cost (0.17); thus only (design, Content, translation, enabling feature and cost) are accepted as they have passed the first condition. The second criterion is that each item's value should be more excellent than 75%. With a total percentage of 86 per cent, the design, Content, recognition, translation, enabling feature and cost with values of (88%, 100%, 88%, 88%, 59% and 94%) respectively. This shows that (design, Content, recognition, translation and cost) are accepted as the value is more than 75%. The average of fuzzy numbers should be greater than 0.5 in the third criterion. Design, Content, recognition, translation, enabling feature and cost were scored (0.682, 0.671, 0.671, 0.706, 0565 and 0.682). This shows that all these sub-criteria have been accepted as they have passed the third condition. Only sub-criteria that pass all three conditions will be accepted per the Fuzzy Delphi method. Therefore, only (design, Content, translation and cost) are selected as they passed all three Fuzzy Delphi conditions.

4. DISCUSSIONS

People turn to their mobile devices as a primary means of communication, entertainment, and access to essential services. Mobile apps have revolutionized sign language learning by providing accessible, interactive, and personalized learning platforms. They have expanded the reach of sign language education and empowered individuals to learn and communicate in sign language more effectively. Assessing the criteria of sign language mobile apps is crucial to ensure their effectiveness and quality. While looking at academic literature, it turned out that most sign language mobile apps have been mainly assessed by either conducting in-house testing and evaluation or running these apps in different experimentations set by their developers and authors. None of these apps had undergone a quality assessment in terms of a standardized approach except for one study by [7], where authors performed a quality assessment on mobile apps for sign language using the Mobile Apps Rating Scale (MARS). Because of domain issues, MARS criteria are insufficient for assisting sign language mobile app assessment and are instead used for general mobile app assessment. As a result, more reliable assessment criteria are required with a robust list of criteria. The MARS criteria, which is considered a valid and reliable scale for evaluating mobile apps, is used in this study. The study introduces a novel MARS modification to create a sturdy list of criteria to address the challenges of mobile app evaluation. MARS criteria were kept without being omitted, and after reviewing the literature, researchers discovered that additional criteria were mentioned in the articles. These criteria from the literature review were collected and were then standardized using the Fuzzy Delphi method, yielding four main criteria that were agreed upon by seventeen experts. The limitations of this study are that it focuses only on sign language mobile apps, and the most challenging part of the process is the evaluation. This study addresses evaluation issues with various criteria to provide a fair and accurate performance process without regard for the evaluated mobile app's ranking or prioritizations.

5. CONCLUSION

Evaluating mobile apps, particularly those focused on sign language, is a critical area that requires more attention and research. Despite the limited number of studies conducted on sign language mobile apps, this paper proposes a mobile app quality assessment protocol to assess the quality of such apps using various criteria and experimentation. The criteria were gathered from relevant articles and standardized using the Fuzzy Delphi Method, leading to a consensus among 17 experts. By establishing reliable criteria for assessing sign language mobile apps, this assessment will catalyze the development of improved apps, benefiting the fields of research, academia, and everyday use. Furthermore, this research can also serve as a benchmark for mobile app developers, particularly those focused on sign language, offering a standardized point of reference against which their apps can be compared. Developers can utilize the proposed assessment protocol to evaluate and enhance the quality of their apps, striving to meet the established criteria and delivering better user experiences. Ultimately, this research contributes to the advancement of sign language mobile apps and promotes overall quality and innovation within the broader mobile app development industry.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Data availability

N/A

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