Expert Consensus on Formation of Design Principles for Malay Sign Language Mobile Application Based on Nielsen's and Molich's Design Guidelines

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Abstract – **Malay Sign Language (MSL) is a Malay spoken language that hearing-impaired (HI) learners use in communication and learning in Malaysia. Various MSL mobile applications have been developed and available in the market to support the HI learners in learning sign language, but most fail to satisfy the learners' needs and consist of many drawbacks in functionalities. Besides, the existing MSL mobile applications fail to evoke the cognitive ability among HI learners. Thus, this study aims to propose an MSL mobile application that hybridizes Nielsen's and Molich's Design Guidelines (NMDG) in order to evoke the cognitive ability among HI learners and provide mobile applications that meet the user's needs.**

Before developing the proposed application, this study has carried out the initial investigation that has been done through User-Centered Design (UCD) in stage 1. Hence, the evolution of NMDG was identified, but they are too generic as it does not consider the HI alpha generation context in evaluating the mobile application. Hence, new design principles that consider HI alpha generation will be formed throughout the extension of the study based on the NMDG.

1. Introduction

According to the World Health Organization (WHO), over 5% of the world's population suffers from hearing loss, approximately 432 million adults and 34 million children. However, the numbers are expected to be risen by 2050 to 700 million people [4]. Besides, according to the data of registered hearing-impaired (HI) individuals in Malaysia by the Department of Statistics Malaysia, as shown in Figure 1, the number of registered HI individuals rose from 2016 (31,937) to 2018 (44,523), then declined in 2019 (35,991) and grew in 2020. (39, 935). Thus, based on the trends and data, the numbers in both adult and child categories are predicted to rise. Hence, this study will benefit more HI learners, including the alpha generation based on the statistics.
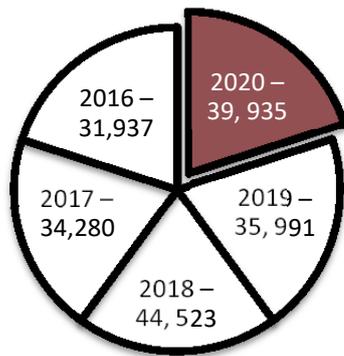
Figure 1. Statistics of Hearing-Impaired People in Malaysia (2016-2020)

Besides, another phenomenon that triggers the acceleration of this study is the Malaysian law's goal to guarantee that by 2025, around 75% of children with disabilities, including HI learners, will have access to an excellent educational environment to learn more effectively. To achieve the goals, Malaysia has partnered with 192 other world leaders to accept the 2030 Agenda for Sustainable Development Goals (SDGs). There are 17 aims, one of which is quality education, which falls under the fourth aim. Quality education promotes lifelong learning and ensures equal opportunities for all learners, including people with disabilities (PWDs), to ensure that all of them receive the same learning content and ensure that they are not left behind.

In Malaysia, all the HI learners, especially the alpha generation, who are the children born after 2010, are required to register into the special schools to get proper and standard education [3]. All the HI learners use the Malay Sign Language (MSL) to support their communication and learning at school. This aims to ensure that all HI learners in Malaysia utilize the same types of sign language to minimize misunderstandings in communication [13]. However, due to the impacts of COVID-19, around 90% of the learners were impacted by the school closure and hurt their academic achievement. As a result, the government has imposed the Online Distance Learning (ODL) program, where the usage of e-Learning has grown ubiquitous. Besides, the alpha generation has developed an interest in compact and portable devices, such as smartphones and tablets, to support their learning activities [17]. Thus, communication between humans and mobile devices occurs, referred to as "Mobile Human-Computer Interaction (MHCI).

1.1. Mobile Human-Computer Interaction (MHCI)

Mobile Human-Computer Interaction (MHCI) can be characterized as communication between humans and mobile devices as the small type of screen interface and convenience of carrying make them increasingly popular [11]. They may eventually supplant the desktop and laptop as the most used Human-Computer Interaction (HCI) hardware. However, mobile devices are still a part of HCI since it also involves the interaction between users and the computer systems embedded in the mobile devices. On the other hand, Mobile Interaction Design (MID) will oversee designing the computer system embedded in mobile devices. Ensuring that the devices and applications are accessible to all users is critical, particularly the PWDs. However, developing technology for PWDs, especially the alpha generation, is challenging for designers as they need to ensure that the design is reliable and suitable enough according to the users' state [7]. The mobile devices specifically designed for disabled people are also known as Assistive Technology (AT).

1.2. Assistive Technology (AT)

Individuals with Disabilities Education Act (IDEA) defined assistive technology (AT) as "any item, piece of equipment, or product system that is used to increase, maintain or improve functional capabilities of individuals with disabilities" [6]. AT covers a wide range of assistive, adaptive, and rehabilitation devices for PWDs. It can be classified into hardware-based, software-based, and prosthetic implants. Three categories of AT are designed explicitly for HI people: the Assistive Listening Devices (ALD), Augmentative and Alternative Communication as described in Table 1.

On the other hand, according to National Centre on Accessible Instructional Materials (2013), the usage of AT in disabled learners needs to be considered to support them in their learning and provide a comfortable learning environment [6]. From Table 1, sign language learning applications can be seen as a part of AAC categories. It is one of the education approaches to support HI learners in sign language learning. Most HI alpha generation depends on the sign language interpreter to communicate with society [16].

Table 1. Categories of Assistive Technology (AT)

Categories of AT	Description
Assistive Listening Devices (ALD)	Amplify weak audio signals or waves for deaf people in significant areas such as airports, conveying the information through audio medium. Objective and subjective evaluations of the speech enhancement methods present an excellent improvement in the quality and intelligibility of speech signals.
Augmentative and Alternative Communication (AAC)	People with hearing impairment or language disability use gestures or sign language, computer-generate speech, or text for effective communication. The users need to learn and understand the meaning.
Alert System	Alert or alarm systems use a flashlight, highly amplified sound, vibration to alert deaf people when a specific event occurs. Fire alarm, baby-cry alarm, and doorbell have lost their hearing capability; then, Gesture language is the first most preferable. An average person hardly understands the gestures, so various sign language recognition and learning tools focus on teaching and understanding sign language to an average person.

1.3. Existing Malay Sign Language (MSL) Mobile Application (2017 – 2021)

Various MSL mobile applications are currently available in the market, as shown in Table 2. However, [2] found that the existing MSL mobile applications fail to hybridize Nielsen's and Molich's Design Guidelines (NMDG) in their study during the evaluation phase, which is critical for evoking cognitive ability among HI learners. Besides, most mobile applications fail to meet the needs of HI learners in terms of user interface and functional limitations. This issue has impacted the educational quality of the HI alpha generation. As a result, the existing MSL mobile applications cannot offer good learning experiences for the HI alpha generation. Hence, this study aims to provide an MSL mobile application that hybridizes the NMDG to assist HI learners in learning the MSL. Based on previous research, it was found that the existing NMDG is too generic as they are not considering the HI alpha generation context in evaluating the mobile application. Thus, the extensions of design principles based on NMDG that considers the HI alpha generation will be formed throughout this study.

Table 2. Existing MSL Mobile Application (2017 -2021)

No.	Application / Features	Author / Developer	Language
1	**Basic Malaysian Sign Language**	[12]	Malay
2	**E-Learning Malaysian Sign Language**	[9]	English
3	**Malaysian Sign Language Mobile Learning and Sign Detection**	[8]	English
4.	**Mobile Dictionary for Hearing-Impaired**	[14]	Malay
5	**My Bahasa Isyarat Malaysia-MyBIM**	[15]	English and Malay

1.4. Nielsen's and Molich's Design Guidelines (NMDG)

Nielsen's and Mollich's Design Guidelines (NMDG) is a heuristic evaluation that Jakob Nielsen introduced in 1990. This method includes a small number of evaluators to evaluate and observe the user interface and provide feedback and comments based on the design guidelines [10]. It is called heuristics as it covers broad perspectives that are appropriate with the development of mobile applications, and it can customize according to user needs [2]. The NMDG has been evolved from 1990 to 2019 that can be described as follows:

1.4.1. Nielsen's and Molich's Design Guidelines (NMDG) by Jakob Nielsen (1990)

In 1990, there were nine guidelines formed by Jakob Nielsen, as shown in Table 3 by Nielsen & Molich 1990. These heuristics were first published in the article "Improving a human-computer dialogue" by Rolf Molich and Jakob Nielsen in Communications of the ACM in March 1990.

Table 3. Nine NMDG by Jakob Nielsen's in 1990

No	Guidelines
1	Simple and natural dialogue
2	Speaks the user language
3	Minimize user memory load
4	Be consistent
5	Provide feedback
6	Provide clear marked exits
7	Provide shortcuts
8	Provide good error messages
9	Error prevention

1.4.2. Nielsen's and Molich's Design Guidelines (NMDG) by Jakob Nielsen (1994)

However, in 1994, the guidelines were reformed by adding another design guideline for software inspection. It is a method for debugging and improving code and usability inspection to evaluate the user interface, as shown in Table 4 [10]. Thus, there are ten design guidelines that have been formed by Nielsen and Molich.

Table 4. Ten NMDG by Jakob Nielsen's in 1994

No	Guidelines
1	Simple and natural dialogue
2	Speaks the user language
3	Minimize user memory load
4	Be consistent
5	Provide feedback
6	Provide clear marked exits
7	Provide shortcuts
8	Provide good error messages
9	Error prevention
10	Help and documentation

1.4.3. Nielsen's and Molich's Design Guidelines (NMDG) for Mobile Application by Kumar (2019)

However, [10] found that the existing NMDG is impractical for mobile application evaluation because it is too generic and does not consider the mobile application context. Thus, the guidelines have been reformed by adding three new guidelines: selection-driven commands, content organization, and visual representation, as shown in Table 5.

Table 5. 13 Nielsen's and Molich's Design Guidelines (NMDG) for Mobile Application by Kumar in 2019

No	Heuristics	Evaluation
1	Visibility of the system status	providing appropriate feedback when the user is accessing a mobile learning application
2	Match between the system and real world	Quickly recognized the use of text and enabled the users to identify the elements on the apps quickly
3	User control and Freedom	use of text and icons which are intuitive and easily recognizable, which enables users to identify and comprehend elements on the app quickly
4	Consistency and Standards	allow individuals to go to different menus with ease and the ability to exit and enter different selections of the application quickly
5	Error Preventions	mobile learning application having consistent and similar features to any other mobile learning application
6	Recognition Rather than Recall	users can complete tasks in a mobile learning application with minimum or no errors and quickly recover from errors
7	Flexibility and Efficiency of Use	minimizing user's memory load while using a mobile learning application, users should not feel pressured to remember information or features while using the application
8	Aesthetics and Minimalist Design	concentrates on the speed of interaction to cater for both novice and expert users; hence should be able to adjust to a person's rhythm
9	Help users recognize, diagnose, and recover from errors	eliminating unnecessary information from a mobile learning application. Unnecessary information can make it difficult to reach out to relevant information.
10	Help and Documentation	assist users in finding specific content, assist in learning the application, provide help and guidance in identifying elements in the app, provide examples to perform tasks, and assist in completing crucial tasks.
11	Selection driven commands	users are engaged with selection rather than typing or feeding data, menu, or list selection, use of buttons and user control interface is used instead
12	Content organisation	the content needs to highlight key learning objectives, some elements of the content organisation are content would need to be optimized to fit in one screen, multiple screens can be used to display content if the content is large
13	Visual representation	use of pictures, icons, screen objects, sound, text colour, background colour, and animations to help the user learning process

2. Methods and Materials

This study is based on a qualitative approach to gain deep insight into how MSL mobile applications could support HI alpha generation in their studies. The qualitative research design provides a chance to understand better how sign language affects learners' education. This approach was chosen due to the condition of the primary respondents as they are the HI children. Thus, they need a less complex and naturalistic approach to understand them while participating in this study. Besides, the respondents

need extra attention as they are children with disabilities. Their behaviour provides meaningful and valuable data and ensures the richness of data.

Then, this study also applies the User-Centered Design (UCD) Approach as UCD is a process of designing the product by focusing on usability goals, user characteristics, environment, task, and workflow [1]. There are four stages involved within the UCD process which are (i) Understanding and specifying the context of use; (ii) Understanding and specifying the user requirement; (iii) Iteration and proposed design solution, and (iv) Evaluating the solution with the user against requirements. However, as for the context of this paper, only two processes were applying as shown in Figure 2.
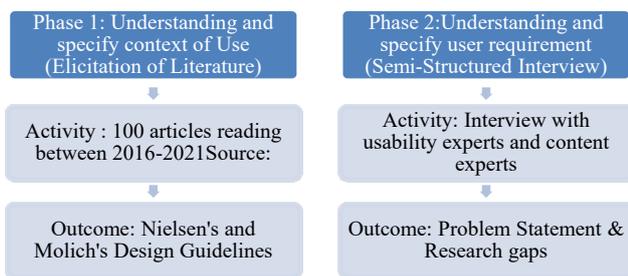
Figure 2. Summarization of Methods Involves

2.1. Elicitation of Literature

As for stage 1, the study context was elicited through the literature reading from various databases. The journal considered was only the journals or articles published after 2017. The articles were examined closely to ensure they followed the CEC standards. There were 100 articles reviewed from the Google Scholar database, Scopus Journal, and UUM Library. However, only 19 articles were for this paper as the points were relevant. The list of articles that have been cited was as stated in the reference sections. From the elicitation of the literature, the evolution of NMDG was identified.

2.2. Semi-Structured Interview for Preliminary Studies

Then, in stage 2, a semi-structured interview for the preliminary study was done. Six experts were involved as three experts are usability experts and three are content experts. The objectives of this preliminary study are (i) to get information on the current issues and problems that arise regarding the use of MSL mobile applications among HI alpha generations and their teachers; (ii) to identify user's

needs and views on MSL mobile application, and (iii) to identify the views from experts on the importance and suitability of hybridizing NMDG into MSL mobile application.

Few phases were involved before the interview questions were developed, as shown in Figure 3. The questions were adopted from the study made by [5]. Then, the questions were designed to gain insight into a few crucial pieces of information, which are: (i) challenges faced by the actual user in learning sign language using the current method; (ii) current methods used for sign language learning and teaching; (iii) problems and issues arise in the current method; (iv) to gain insight on the behaviour of the HI alpha generation with the mobile; (v) suggestions to enhance the mobile application, and (vi) the importance and suitability of hybridizing NMDG into MSL mobile applications. Thus, two versions of interview questions were designed for two types of experts, as shown in Table 6, and usability experts, as shown in Table 7. However, due to COVID-19, face-to-face interviews were not allowed; thus, the interviews were conducted virtually through the Zoom Meeting platform.
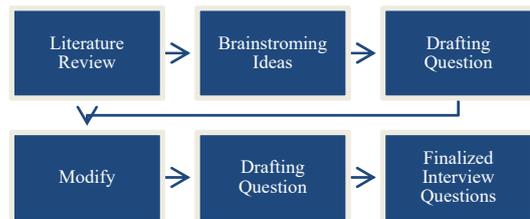
Figure 3. Phases Involved in Conducting Interview

Table 6. Preliminary Interview Questions for Content Experts

NO	QUESTIONS	OBJECTIVES
1	What are the biggest challenges of these children in learning sign language?	Challenges faced by the actual user in learning sign language using the current method.
2	What is the current method of learning sign language?	Current methods used for sign language learning and teaching.
3	What is the problem with the current method?	Problems and issues arise in the present method.
4	How do the learners interact with the current learning method?	
5	How could it be improved?	Suggestions to enhance the mobile application.

Table 7. Preliminary Interview Questions for Usability Experts

NO	QUESTIONS	OBJECTIVES
1	Are you aware of or familiar with any MSL mobile applications? Such as MyBIM	Gain experts' thoughts on the research area
2.	What are your thoughts on the app's functions and user interface? Do you think that it will affect the users' satisfaction?	Research Gaps / Problems on existing apps
3.	What suggestions do you have for improving the apps? Do you think the existing MSL mobile application needs to be enhanced in multimedia elements and functionalities suitable for the HI alpha generation context?	Research Gaps / Problems on existing apps
4.	When developing this guideline, do you believe a mobile application must consider HI children's cognitive skills?	Gain experts' thoughts on the research area
5.	When developing this guideline, do you believe a mobile application must consider HI children's cognitive skills?	Gain experts' thoughts on the research area
6.	Do you believe that existing MSL mobile applications, such as those you described before, should be improved by using this rule while building them?	Research Gaps / Problems on existing apps
7.	Do you think the guidelines need to be reformed because the existing NMDG does not consider HI alpha generation? And do you believe that the existing NMDG for mobile applications is too generic and unsuitable for the HI context?	Research Gaps / Problems on existing apps
8.	Can you explain which of the guidelines relates to designing an MSL mobile application for HI? Or do you have other additional guidelines that come to your mind?	Gain experts' thoughts on the research area
9.	Do you have any other design guidelines that you think should be adopted in addition to this one?	Gain experts' thoughts on the research area
10.	Finally, do you have any more thoughts on how to improve this research?	Gain experts' thoughts on the research area

3. Results and Findings

As a result, three content experts who are the teachers of HI learners and three usability experts who are the lecturers in HCI, and user experience fields participated in the interview session. Table 8 shows the thematic analysis results of the interview session with the content experts who are the teachers of HI alpha generation.

According to content expert 1, the HI alpha generation was currently having problems memorizing and understanding sign language vocabulary, also known as a cognitive disability. The HI alpha generations rely entirely on textbooks to learn sign language vocabulary. However, the textbooks fail to attract the learners' interest due to the unattractive learning materials since the textbooks lack a variety of colors and graphics.

Then, content expert 2 said that the teachers had taken the initiative to use their PowerPoint slides to teach the learners. Still, they found that the slides were not enough as the learners need extra exercise that they can practice by themselves without assistance. It is good if the practice is also in animation or video as it can enhance their cognitive ability to memorize and understand the sign language contents. Next, content expert 3 said that the HI learners are familiar enough with using mobile devices. However, most existing mobile applications do not follow the Malaysian education standard and fail to satisfy the HI learners' needs due to the unattractive user interface.

Table 8. Thematic Analysis on Content Expert Interview Result

Quotations	Code	Theme
/…Currently, the students are having problems in memorizing and constructing sentences…. /	Learning Problems	Research Gaps
/…Currently, the students are using the learning materials provided by schools, but they hard to remember the vocabulary to construct sentences and the sign language associate with it…/	Learning Problems	Research Gaps
/… The teachers are using PowerPoint to attract the students' interest, but most of the slow learners' students tend to be having difficulties in constructing sentences due to being unable to memorize the vocabularies and the sign …/	Learning Problems	Research Gaps
/… Current teaching materials such as books provided fails to attract the	User Interface	Research Gaps

students' interest as they need more colorful and books with cartoon to attract their interest…/		
/… Besides, the fonts used are essential as the students recognize the words from the font used…/	User Interface	Suggestion
/… Apart from that, the learning content must follow the Ministry of Education in Malaysia to avoid misunderstanding and ensure the students learn similar types of sign language…/	Learning Content	Suggestion
/… I suggest the learning content more on learning vocabularies and constructing sentences because most of the students have problems doing so…/	Learning Content	Suggestion
/… I agree this application be built as it can attract the students' interest due to the multimedia used such as video, cartoon, and animation…/	Learning Content	Suggestion

As for the interview with usability experts, it can be concluded that most of the experts agree that hybridizing NMDG in developing MSL mobile applications could evoke the cognitive ability among HI alpha generation. Table 9 shows the thematic analysis results of the interview session with three usability experts. Usability expert 1 agrees that the user interface is the crucial element when designing the mobile application for HI as they rely more on visuals than audio. Thus, they need an attractive user interface to enhance their cognitive ability when capturing some information. The expert also stated that a mobile application has to satisfy the user's needs, and if it fails, the mobile application is a failure.

Furthermore, usability expert 2 confirms that NMDG needs to be reformed by considering the HI alpha generation context. Besides, usability expert 2 also mentioned that the existing NMDG is generic and does not consider the HI alpha generation context. However, the NMDG elements can be extracted to suit the needs of the HI alpha generation context.

Table 9. Thematic Analysis on Usability Expert Interview Result

Quotations	Code	Theme
/… Functionality and multimedia components are part of the user interface. Functionality, navigation and how we structure the contents, the laying out of the contents. Those are part of the user interface that will lead to user satisfaction or user experience. If they are designed well, yes, it will increase user satisfaction. But if they are poorly designed, it will lead to user frustration. So, it is part of the designers' job. If the designer thinks they have designed it well but not designed it suitable for the target user, it is not well for the target user. It may be well for the designer but not for the target user as it is not designed as desired by the target users…/	User Interface	Research Gaps
/…Maybe the HI did not get benefits and was not helpful. So if you want to upgrade the existing apps, you have to see the usefulness of the apps. Perhaps you can assess what lacking in the system, such as unattractive user interface because user interface might affect the HI attention…/	User Interface	Research Gaps
/… Yes, HI alpha generation needs more attractive user interfaces such as more colors and animation. From the existing MSL mobile application, which is MyBIM, I can see it does not provide an attractive user interface as the use of colors are dull…/	User Interface	Research Gaps
/…Yes, I agree that NMDG need to be reformed by considering the HI context since currently, the existing NMDG is general for all types of users and does not focus on HI…/	NMDG	Research Gaps
/…I can see that the existing NMDG is a bit general, and it can be extracted more to make it suitable in evaluating the mobile	NMDG	Research Gaps

applications for HI. Thus, the guidelines need to be added by considering HI context…/		
/…Yes, I agree that NMDG was able to evoke cognitive ability. But it would be best if you discussed more on the interface. It can relate to motivation…/	NMDG	Suggestion
/… I agree that hybridizing NMDG in developing mobile applications could evoke the cognitive ability among HI people as guideline number six in NMDG states that the recognition rather than recall,…/	NMDG	Suggestion

3.1. Justification of Findings

According to the results discussed, the research problems and research gaps were discussed by both categories of experts. Most of them agreed that most HI learners, especially the alpha generation, are having difficulties memorizing and understanding the learning contents, especially the sign language contents. Besides, they need an attractive way of learning. This is to enhance their cognitive ability in learning the contents. For HI learners, understanding and memorizing sign language are crucial since they could communicate with society.

Thus, most usability experts agreed that hybridizing NMDG could enhance the cognitive ability among HI alpha generation. However, they suggest expanding the existing guidelines by considering the HI context. From the interview, they have offered a few design guidelines to be added that can be described as follows:

I. People learn better from animation with narration rather than static images.
II. Minimize the number of elements displayed on the screen. It is advisable to have between 5 to 7 numbers of elements on the screen.
III. The usage of colours is essential when it comes to children.
IV. Use the animation that the children are familiar with.
V. Use more simple words for the children to enhance their cognitive ability.

Besides, they suggest mapping the NMDG with the multimedia cognitive theory for better results since the users are people with disabilities. Lastly, the experts indicated that having MSL mobile applications suitable for the HI learners' condition will help the students enhance their understandability and memorability towards sign language learning.

4. Conclusion

In a nutshell, all HI learners are required to master learning MSL. Besides, having MSL mobile application can provide an attractive way of learning MSL and evoke the cognitive ability among HI learners. However, the MSL mobile applications need to hybridize the NMDG to ensure the applications able to evoke the cognitive ability among HI learners. Findings from the literature review and virtual interviews sessions with the experts show that hybridizing NMDG can help the HI learners enhance their understandability and memorability in learning MSL.

Acknowledgements

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