MOBILE APPLICATION DESIGN PRINCIPLES BASED ON NIELSEN'S AND MOLICH'S DESIGN GUIDELINES (NMDG) FOR HEARING-IMPAIRED MALAY SIGN LANGUAGE (MSL)

ERMIERA SHAFIKA BINTI MOKHTAR

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Awang Had Salleh
Graduate School
of Arts And Sciences

Universiti Utara Malaysia

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Pemeriksa Dalam: *(Internal Examiner)*	**Dr. Nadia Diyana Mohd Muhaiyuddin**	Tandatangan *(Signature)*
Nama Penyelia/Penyelia-penyelia: *(Name of Supervisor/Supervisors)*	**Dr. Azizah Che Omar**	Tandatangan *(Signature)*
Nama Penyelia/Penyelia-penyelia: *(Name of Supervisor/Supervisors)*	**Ts. Dr. Nurulnadwan Aziz**	Tandatangan *(Signature)*

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Abstrak

Kajian ini memfokuskan pembentukan prinsip reka bentuk aplikasi Bahasa Isyarat Malaysia untuk generasi alfa yang menghadapi masalah pendengaran berdasarkan garis panduan reka bentuk yang telah diperkenalkan oleh Nielsen dan Molich. Pelbagai aplikasi mudah alih telah direka dan dibangunkan bagi menyokong pembelajaran kanak-kanak yang menghadapi masalah pendengaran untuk mempelajari bahasa isyarat dengan interaktif. Dapatan awal kajian telah mendapati bahawa aplikasi yang telah dibangunkan gagal membentuk kemahiran kognitif di kalangan para pelajar yang menghadapi masalah pendengaran. Kemahiran kognitif sangat penting untuk memperkukuhkan pemahaman para pelajar. Walaubagaimanapun, kajian lepas mendapati bahawa garis panduan Nielsen dan Molich yang telah diperkenalkan tidak mengambil kira konteks kanak-kanak yang menghadapi masalah pendengaran. Oleh yang demikian, kajian ini mengusulkan pembentukan prinsip reka bentuk bagi aplikasi Bahasa Isyarat Malaysia untuk generasi alfa yang menghadapi masalah pendengaran berdasarkan garis panduan reka bentuk yang diperkenalkan oleh Nielsen dan Molich yang telah diperbaharui dengan mengambil kira aspek aplikasi mudah alih. Dua objektif kajian telah dibentuk. Metodologi Kajian Sains Rekabentuk telah diadaptasi. Enam belas elemen prinsip reka bentuk telah dikenalpasti. Prinsip kajian yang diusulkan telah dinilai dan disahkan melalui tiga metod pengesahan iaitu penilaian pakar, pembangunan prototaip, dan pengujian pengalaman pengguna. Lima orang pakar telah dipilih bagi menilai prinsip reka bentuk yang telah diusulkan melalui aktiviti penilaian pakar. Kemudian, prototaip separa kerja telah berjaya direka dan dibangunkan. Dapatan daripada pengujian pengalaman pengguna telah menunjukkan bahawa prinsip kajian yang diusulkan telah berjaya memenuhi kehendak dan keperluan generasi alfa yang mengalami masalah pendengaran, memandangkan mereka dapat menyempurnakan tugasan yang diberi dalam masa yang ditetapkan. Dapatan ini telah menunjukkan bahawa prinsip kajian yang diusulkan dapat menjadi rujukan kepada penyelidik di masa akan datang untuk membangunkan aplikasi mudah alih Bahasa isyarat Malaysia bagi pelajar yang menghadapi masalah pendengaran, terutamanya generasi alfa.

Kata Kunci: Teknologi bantuan, Interaksi manusia dan aplikasi mudah alih, Reka bentuk pengguna berpusat, Garis panduan reka bentuk nielsen dan molich, Pendengaran terjejas.

Abstract

This study is primarily concerned with constructing the Malay Sign Language (MSL) mobile application design principles for the hearing-impaired (HI) alpha generations based on Nielsen's and Molich's Design Guidelines (NMDG). Numerous MSL mobile applications have been developed and are currently available in the market to support HI learners in learning sign language interactively. Preliminary studies found that the existing MSL mobile applications fail to elicit cognitive abilities among HI learners, which is critical for improving their memorability and understanding of sign language. Previous researchers suggested hybridizing the NMDG in developing the MSL mobile applications since it could evoke cognitive ability among the users. However, the existing NMDG does not consider the context of the HI learners. Therefore, this study proposes new design principles for the MSL mobile application based on the NMDG. Two specific objectives were formulated. The Design Science Research Method (DSRM) has been adopted. Sixteen design principles were constructed through the User-Centered Design (UCD) approach. Then, the design principles were validated through three validation approaches which are expert review, prototyping, and user experience testing, to ensure it is useful and reliable. Five experts with different backgrounds were chosen to validate the design principles. Next, a semi-working prototype was successfully designed and developed based on the proposed design principles. The findings of the user experience testing indicate that the design principles can fulfil the needs of the HI alpha generations. Additionally, it can evoke cognitive ability as they can memorize and understand the application by completing the tasks within the allotted time without distractions. These findings demonstrate that the design principles can act as a manual for future researchers designing and developing the MSL mobile application for HI learners, particularly the HI alpha generations.

Keywords: Assistive technology (AT), Mobile human-computer interaction (MHCI), User-centered design (UCD) approach, Nielsen's and Molich's design guidelines (NMDG), Hearing-impaired (HI).

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Table of Contents

Permission to Use……ii

Abstrak iii

Abstract iv

Acknowledgement v

Table of Contents vi

List of Tables xii

List of Figures xiv

List of Appendices xvii

CHAPTER ONE INTRODUCTION 1

1.1 Overview 1

1.2 Background of Study 1

1.3 Research Motivation 5

1.3.1 Statistics of Hearing-Impaired (HI) People in Malaysia (2016 – 2020) 5

1.3.2 Government Supports and Initiatives 6

1.3.3 Summary of Research Motivation 7

1.4 Background of Research Problem 8

1.4.1 Preliminary Study 8

1.4.1.1 Methods 8

1.4.1.2 Results and Findings 12

1.4.2 Research Problem 16

1.4.2.1 Research Gaps and Research Questions 21

1.5 Proposed Solution 21

1.6 Research Objectives 22

1.7 Research Scopes 22
1.8 Research Significance 23
1.8.1 Design Principles of MSL Mobile Application for HI Alpha Generations 23
1.8.2 Prototype of MSL Mobile Application for HI Alpha Generations 23
1.8.3 Empirical Findings 24
1.9 Theoretical Framework 25
1.10 Operational Terminologies 27
1.11 Thesis Structure 30
1.12 Chapter Summary 33
CHAPTER TWO LITERATURE REVIEW 34
2.1 Overview 34
2.2 Human-Computer Interaction (HCI) 34
2.3 Mobile Human-Computer Interaction (MHCI) 36
2.4 Mobile Interaction Design (MID) 37
2.5 Assistive Technology (AT) 37
2.6 Alpha Generations 41
2.7 Hearing-Impaired (HI) Alpha Generations 43
2.8 Malay Sign Language (MSL) 44
2.9 Usability Heuristics Evaluation 45
2.9.1 Nielsen's and Molich's Design Guidelines (1990) 46
2.9.2 Nielsen's and Molich's Design Guidelines (1994) 48
2.9.3 Nielsen's and Molich's Design Guidelines (2019) 49
2.9.4 Summary Evolutions of Nielsen's and Molich's Design Guidelines 51
2.10 Existing MSL Mobile Applications 52

2.10.1 3D Sign Language: The Development of Mobile Learning Application (2022) 52
2.10.2 Basic Malaysian Sign Language Mobile Application (2021) 55
2.10.3 E-Learning Malaysian Sign Language (2019)..... 59
2.10.4 Mobile Dictionary for Hearing-Impaired (2019)..... 63
2.10.5 Comparative Analysis of the Existing MSL Mobile Applications..... 69
2.11 Chapter Summary 72
CHAPTER THREE RESEARCH METHODOLOGY..... 75
3.1 Overview..... 75
3.2 Rationale for Adopting Qualitative Approach..... 75
3.3 Triangulation Method 76
3.3.1 Data Triangulation..... 77
3.3.2 Researcher Triangulation..... 77
3.3.3 Methodological Triangulation 78
3.4 Rationale for Adopting Iterative Triangulation Method (ITM)..... 79
3.5 Rationale for Adopting Design Science Research Method (DSRM)..... 79
3.6 Phases in Research Methodology 80
3.6.1 Phase 1: Problem Awareness..... 83
3.6.1.1 Research Planning..... 84
3.6.1.2 Content Analysis I..... 84
3.6.1.3 Preliminary Interview 85
3.6.2 Phase 2: Suggestions 86
3.6.2.1 Content Analysis II 87
3.6.2.2 Comparative Analysis..... 87
3.6.3 Phase 3: Construction 88

3.6.3.1 Experts' Consultations 88
3.6.3.2 User-Centered Design (UCD) Approach 89
3.6.4 Phase 4: Validation 91
3.6.4.1 Sampling 92
3.6.4.2 Validation through Expert Review Method 92
3.6.4.3 Validation through Prototyping Method 93
3.6.4.4 Validation through User Experience Testing Method 95
3.6.5 Phase 5: Conclusion 97
3.7 Chapter Summary 97
CHAPTER FOUR CONSTRUCTION OF THE DESIGN PRINCIPLES FOR THE MSL MOBILE APPLICATION THROUGH UCD APPROACH 99
4.1 Overview 99
4.2 Expert Consultations 100
4.2.1 Background of Experts 100
4.2.2 Instruments and Methods 101
4.2.3 Results and Findings of the Expert Consultations 103
4.3 User-Centered Design (UCD) Approach 107
4.3.1 Participants 108
4.3.2 Instruments and Methods 109
4.3.3 Results and Findings 110
4.4 Chapter Summary 116
CHAPTER FIVE EXPERT REVIEW 117
5.1 Overview 117
5.2 Expert Review 117
5.3 Experts' Demographic 118

5.4 Methods and Procedures 120
5.5 Results and Findings 122
5.6 Justifications of Results and Findings 129
5.7 Chapter Summary 136
CHAPTER SIX PROTOTYPING OF THE MSL MOBILE APPLICATION 137
6.1 Overview 137
6.2 Development of the MSL Mobile Application Prototypes 137
6.3 Initial Prototype of MSL Mobile Application 138
6.4 Semi-Working Prototype of MSL Mobile Application I 139
6.5 Semi-Working Prototype of MSL Mobile Application II 140
6.6 Chapter Summary 157
CHAPTER SEVEN USER EXPERIENCE TESTING ON THE MSL MOBILE APPLICATION 158
7.1 Overview 158
7.2 Special Requirements on User Experience Testing with HI Alpha Generations. 158
7.3 Direct Observation 161
7.4 Pilot Test 163
7.4.1 Methods and Procedures 163
7.4.2 Results and Findings 165
7.4.2.1 Problems with MSL Prototype 166
7.4.2.2 Problems with Data Collection Method 167
7.4.3 Justifications of Results and Findings 169
7.5 User Experience Testing 169
7.5.1 Demographic of the Subjects 170
7.6 Direct Observation 1 171

7.6.1 Instruments and Methods 172
7.6.2 Results and Findings 174
7.7 Direct Observation 1I 186
7.7.1 Procedures and Methods 186
7.7.2 Results and Findings 188
7.8 Chapter Summary 190
CHAPTER EIGHT CONCLUSION 191
8.1 Overview 191
8.2 Research Question 1: Why are the MSL mobile applications' existing design principles inappropriate for the HI alpha generation? 192
8.3 Research Question 2: How to validate the design principles of the MSL mobile application for HI alpha generation? 193
8.4 Research Objectives: Revisit 194
8.5 Implications of Study to Theory and Practical 195
8.6 Limitations and Recommendations for Future Works 196
8.6.1 Design Principles for the MSL Mobile Application 196
8.6.2 Validation of the Proposed Design Principles 197
8.7 Chapter Summary 198
REFERENCES 200

List of Tables

Table 1.1 Existing Malay Sign Language (MSL) Mobile Applications 3
Table 1.2 Registration of Persons with Disabilities According to Types of Disabilities ... 6
Table 1.3 Preliminary Interview Questions for Content Experts 9
Table 1.4 Preliminary Interview Questions for Academicians 10
Table 1.5 Content Experts' Profile 11
Table 1.6 Academicians' Profile 11
Table 1.7 Thematic Analysis Content Expert Interview Result 12
Table 1.8 Thematic Analysis Usability Expert Interview Result 15
Table 1.9 Existing Application MSL Mobile Application 18
Table 2.1 Categories of Assistive Technology (AT). 38
Table 2.2 Parameters and Examples of AT 40
Table 2.3 Stages of Generation 42
Table 2.4 Nine NMDG by Jakob Nielsen in 1990 46
Table 2.5 Ten NMDG by Nielsen and Molich's in 1994 48
Table 2.6 13 NMDG for Mobile Application by Kumar in 2019 49
Table 2.7 Evolution of NMDG (1990 – 2019) 51
Table 2.8 Suggestions from Experts 68
Table 2.9 Comparative Analysis Result 70
Table 3.1 Fundamental principles of UCD. 89
Table 4.1 Experts' Background 100
Table 4.2 Thematic Analysis of the Consultations with Academicians 104
Table 4.3 Users, Criteria, Justifications for Selecting the Subjects, and Tasks. 109
Table 4.4 Thematic Analysis of the Virtual Discussions with the Teachers 110
Table 4.5 Identified 16 Design Principles for the MSL Mobile Application for HI Alpha Generation Based on NMDG 114
Table 5.1 Criteria of Academicians and Practitioners 118
Table 5.2 Experts' Demographics 119
Table 5.3 Results of the Expert Review 123
Table 5.4 Additional Feedback and Comments from Experts 128

Table 5.5 Sixteen Proposed Design Principles Validated by Experts through Expert Review Method 132
Table 7.1 Suggested Observing and Informative Method for User Experience Testing by Cano (2018) 160
Table 7.2 Problems, Causes, and Solutions Detected in Pilot Test 167
Table 7.3 Demographics of subjects involved 170

List of Figures

Figure 1.1. Phases in constructing interview questions 12
Figure 2.1. Learning contents 53
Figure 2.2. Learning by category 54
Figure 2.3. Quizzes and video learning 54
Figure 2.4. Menu 56
Figure 2.5. Learning content for alphabet and numbers learning categories 57
Figure 2.6. Video learning for greetings learning categories 57
Figure 2.7. Basic conversation learning 58
Figure 2.8. Quizzes 58
Figure 2.9. Main pages and history of msl page 60
Figure 2.10. Learning category pages for alphabet and numbers 61
Figure 2.11. Tutorial page 62
Figure 2.12. Video learning 62
Figure 2.13. Quizzes section 63
Figure 2.14. Welcoming screen 66
Figure 2.15. Learning page 67
Figure 2.16. Summary of chapter 2 74
Figure 3.1. Summarization of research methodology 82
Figure 3.2. Phase 1: Problem awareness 83
Figure 3.3. Phase 2: Suggestions 86
Figure 3.4. Phase 3: Constructions 88
Figure 3.5. Phase 4: Validation 91
Figure 3.6. Phase 5: Conclusion 97
Figure 4.1. Industry expert and research team. 102
Figure 4.2. The industry experts write the answers for feedback 103
Figure 4.3. Sample of the book for sign language learning 106
Figure 4.4. Virtual meetings with users' representatives 110
Figure 6.1. Instruction provides 141
Figure 6.2. Learning contents 142

Figure 6.3. Flexibility of application 143
Figure 6.4. Learning videos and exercises 144
Figure 6.5. Example of font style and size 145
Figure 6.6. Quality of images and videos in prototype 146
Figure 6.7. Pop-out dialogue to prevent error 147
Figure 6.8. Button with symbol 148
Figure 6.9. Familiar characters used in the prototype 149
Figure 6.10. Efficiency and flexibility 150
Figure 6.11. Minimal interface design 151
Figure 6.12. Background color of the prototype 152
Figure 6.13. Help users recover from errors 153
Figure 6.14. Video tutorial 154
Figure 6.15. Click-and-play functionalities for exercises 155
Figure 6.16. Visuals representation 156
Figure 7.1. Pilot Test 162
Figure 7.2. Two Cycles of User Experience Testing (UX) 162
Figure 7.3. Subjects Involved in Pilot Testing 165
Figure 7.4. The subjects involved in the testing 171
Figure 7.5. Introduction Session 173
Figure 7.6. Two groups of subjects 174
Figure 7.7. Subject asking for help to clarify the instructions 175
Figure 7.8. Subject response to the wrong learning content 176
Figure 7.9. Subjects refer to the video and answer the questions 177
Figure 7.10. Subjects zoom in to read the instruction 178
Figure 7.11. Subjects enjoying the video learning 179
Figure 7.12. Subjects happy with the correct answer 180
Figure 7.13. Subjects click on the next button 181
Figure 7.14. Subjects follow the character shown in the video learning 181
Figure 7.15. Subjects skip the video learning 182
Figure 7.16. Subjects enjoying the prototype 183
Figure 7.17. Subjects asking for additional time 185

Figure 7.18. Individual testing 187
Figure 7.19. Smiley for feelings' representations 187
Figure 7.20. Feedback from the subjects for the video learning screen 188
Figure 7.21. Subjects show happy face for the right answer 189

List of Appendices

Appendix A Research Operational Template (ROT)..... 206
Appendix B Lists of NMDG by Kumar (2019)..... 213
Appendix C Sample of Email Invitation for Experts..... 214
Appendix D Sample of Dean's Appointment Letter for Experts..... 215
Appendix E Sample of Checklist for Experts.....**Error! Bookmark not defined.**
Appendix F Sample of Initial Prototype Design..... 219
Appendix G Sample of Initial Semi-Working Prototype..... 220
Appendix H Sample of ERAS Approval Letter..... 221
Appendix I Sample of Approval Letter from Jabatan Pendidikan Khas Malaysia..... 222
Appendix J Sample of Notification Letter for Principal..... 223
Appendix K Sample of Consent Forms..... 224
Appendix L Sample of Rules and Regulations Form..... 229
Appendix M Sample of Evaluation Checklist..... 231

CHAPTER ONE
INTRODUCTION

1.1 Overview

This introductory chapter describes the background of the study, which discusses the current situation and issues related to the study that leads to the analysis's motivation aspects, research problem, preliminary investigation, research gaps, and objectives. It also extensively discusses the research scopes and limitations, the significance, theoretical and research frameworks, and the operational definition of terms used throughout the study.

1.2 Background of Study

Hearing impairment is a sensory problem that affects the auditory system, resulting in hearing loss below 90 decibels (dB) (Downs & Yoshinaga-Itano, 1999). It can affect anyone, particularly the alpha generations, permanently or temporarily. Children born after 2010 who had difficulties utilizing their hearing organs, leading to partial or total loss of hearing, are known as Hearing-Impaired (HI) alpha generations (Baglama et al., 2018). Research by Aziz (2020) also mentioned that most of the HI alpha generations also have cognitive disabilities resulting from hearing impairment, making it difficult for them to interpret and recall learning materials, including the sign language learning contents.

Sign language is the most widely used language for communication among HI individuals worldwide. When writing or typing is too hard, they employ sign language to communicate with the listeners using hand gestures, body language, and lip sync (Bala & Song, 2020).

Different countries employ different versions of sign language, such as American Sign Language (ASL), British Sign Language (BSL), and Pakistan Sign Language (PSL), depending on their dialects and cultures. In Malaysia, there are two versions of sign language available, which are the formal sign language named 'Kod Tangan Bahasa Malaysia (KTBM)' and informal sign language called 'Bahasa Isyarat Malaysia (BIM)' (Chong, 2018). Additionally, formal sign language was used for education, whereas informal sign language was solely used for day-to-day communication (Kamarudin & Hussain, 2019). Hence, formal sign language proficiency is required for the HI learners, particularly the alpha generations, to have a better learning experience.

According to Kamarudin (2019), all HI learners in Malaysia must be registered in the government special schools to receive the proper and standard physical education in sign language. However, recently 90% of Malaysian schools, including special schools for learners with disabilities, were forced to shut down due to the pandemic of Coronavirus Disease 2019 (COVID-19) to reduce physical contact and the spread of the viruses (Azevedo et al., 2020). According to Aliyyah (2020), the Malaysian government has established digital learning initiatives in response to the demands of this situation and the emergence of industrial revolution 4.0 (IR4.0) to ensure that all learners in Malaysia, particularly those with disabilities, are not left behind in education. Hence, numerous mobile learning applications have been designed and developed to support learners, particularly learners with disabilities, to learn interactively. As for the HI learners, various MSL mobile applications are currently available to provide them with a convenient and comfortable learning environment.

However, research by Siong (2021) found that the usability issues and functional limitations of the existing MSL mobile applications prevent them from meeting the users' needs and satisfactions. Aziz (2020) also mentioned that the existing MSL mobile applications fail to evoke cognitive ability among the HI people. Three existing MSL mobile applications were highlighted and discussed by Siong (2021), as tabulated in Table 1.1.

Table 1.1

Existing Malay Sign Language (MSL) Mobile Applications

Name of the Applications	Functionalities	Limitation
EDDY	• 3D animated MSL dictionary. • MSL hand spelling features. • Gamified approach to learning MSL.	• Some buttons are not functioning. • The graphics were overlapping and confusing. • Contents not based on syllabus KTBM.
MYBIM	• Demonstrate gestures for MSL through videos and flashcards. • Includes step-by-step gestures. • 36 categories of gestures and about 500 vocabularies in both Malay and English language.	• Only available for IOS users. • Unattractive interface due to the lack of color combination (black and white picture). • No additional activities are provided, such as quizzes or exercises for the learners to learn interactively. • Contents not based on syllabus KTBM.

Table 1.1 (Continued)

KOTBAM	• Based on syllabus KTBM. • Video for tutorials.	• Limited functionalities due to no additional activities provided, such as quizzes or exercises for the learners to learn interactively.

Source: Siong (2021).

Table 1.1 indicates that only one application named KOTBAM uses the formal sign language for learning contents, while the remaining are not. As for the additional features, only EDDY provides extra features, which are the quizzes to measure the learners' ability to memorize and understand the learning contents, aiming to enhance their cognitive skills. However, EDDY was having usability issues where the buttons provided were not well functioning, and the graphics were overlapping, causing frustration to the users. Then, MYBIM offers better features than other apps since it includes step-by-step sign language gestures and provides videos for learning. Still, its interface is too dull and unattractive since it uses only black and white color for the animations and does not provide any additional features to measure the cognitive ability among the HI learners. Hence, it can be concluded that none of the applications above could satisfy the users' needs with good interface design and better functionalities.

Accordingly, Aziz (2020) advised hybridizing Nielsen's and Molich's Design Guidelines (NMDG) in designing and developing mobile applications since it could stimulate users' cognitive abilities. Jakob Nielsen established ten design principles that serve as the

foundation of NMDG (1994). However, Kumar (2019) found that the existing NMDG does not consider the context of mobile applications. Thus, by considering the context of the mobile apps, the NMDG has been expanded. Still, it does not consider the needs of the HI alpha generations. Therefore, the new design principles for the MSL mobile applications, specifically for HI alpha generations, were constructed based on the extended NMDG throughout this research.

1.3 Research Motivation

Several phenomena have triggered the acceleration of this study. Accordingly, this section summarizes those phenomena that motivate the study as follows:

1.3.1 Statistics of Hearing-Impaired (HI) People in Malaysia (2016 – 2020)

According to Olusanya (2019), World Health Organization (WHO) stated that over 5% of the world's population suffers from hearing loss, with 432 million adults and 34 million children affected, and they estimate that by 2050, almost 900 million individuals are expected to have been added to the population. At the same time, the Department of Statistics Malaysia (2020) states that the number of registered HI individuals rose from 2016 (31,937) to 2018 (44,523). Then, it declined in 2019 (35,991) but grew in 2020 (39 935), as shown in Table 1.2. Based on the trends and data, the numbers in adults and children's categories are predicted to rise. Hence, this study will benefit more HI learners, including the alpha generations, in the future, based on the statistics.

Table 1.2

Registration of Persons with Disabilities According to Types of Disabilities

Types of Disability	Year				
	2016	**2017**	**2018**	**2019**	**2020**
Hearing Impairment	**31,937**	**34,280**	**44,523**	**35,991**	**39,935**
Visual Impairment	36,692	40,466	36,171	43,576	51,306
Physical Impairment	142,600	159,674	179,222	173,587	209,982
Learning Disabilities	143,334	157,714	170,269	169,853	199,352
Speech Problem	2,104	2,355	2,572	2,534	2,948
Mental Problem	33,518	37,537	41,218	40,570	47,981
Others	19,084	21,232	23,415	22,837	27,087
Total	**409,269**	**453,258**	**497,390**	**488,948**	**578,591**

Source: Department of Statistics Malaysia

1.3.2 Government Supports and Initiatives

The Malaysian law's goals for improving support for people with disabilities (PWD) are to guarantee that by 2025, around 75% of children with disabilities, including those in the HI categories, will have access to an excellent educational environment to help them learn more effectively (Othman, 2020). Besides, according to the Official Portal of the Prime Minister's Department's Economic Planning Unit, Malaysia has partnered with 192 other world leaders to accept the 2030 Agenda for Sustainable Development Goals (SDGs). There are 17 aims underlined, and one of them is quality education.

Quality education is the fourth goal highlighted in the SDGs, promoting lifelong learning and equal opportunities for all people, including people with disabilities (PWDs). It ensures that all learners with disabilities receive the same learning experience as others, ensuring they are not left behind. However, in early March of 2019, all Malaysian schools were forced to close due to the pandemic of COVID-19. According to Azevedo (2020), this pandemic has affected all learners, including the HI alpha generations, and hurt their academic achievement due to school closures. As a result, the government has established Online Distance Learning (ODL) as a means for them to continue their learning virtually (Krishnan et al., 2020).

Additionally, due to the cognitive limitations of the HI alpha generations and the failure of the existing MSL mobile applications to evoke cognitive ability, the HI learners are having difficulties in understanding and memorizing the sign language learning contents (Aziz et al., 2020). This issue has impacted the educational quality of the HI alpha generations. Thus, the MSL mobile applications' new design principles were formed throughout this study for future researchers to refer to when designing and developing the mobile applications for HI alpha generations to ensure it could evoke the cognitive abilities among the HI learners.

1.3.3 Summary of Research Motivation

With such significant potential in forming the design principles for the MSL mobile applications based on the NMDG, future researchers may benefit from the new design

principles by utilizing them when designing the mobile applications for HI people, particularly the alpha generations. Mobile applications may advance in the sector given the HI environment, vital market needs, and government support. However, given that this is a significant aspect of the creation of the apps, it is crucial to make sure that the created mobile applications could stimulate the cognitive abilities of the HI learners. Hence, the explanations for this could be further addressed.

1.4 Background of Research Problem

This section describes the background of the research problems extensively as follows:

1.4.1 Preliminary Study

A preliminary study was conducted to develop a research focus and confirm the problem. The analysis of this preliminary study further strengthens the needs of this study.

1.4.1.1 Methods

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 the HI teachers, (ii) to identify the users' needs for MSL mobile applications, and (iii) to get the point of views from the academicians on the importance and suitability of hybridizing the NMDG into MSL mobile applications.

Therefore, open-ended interview questions were constructed as indicated in Table 1.3 and Table 1.4. Few phases were involved before the interview questions were developed, as shown in Figure 1.1. The questions were designed to gain insight into a few crucial pieces of information, which are (i) challenges faced by the actual users 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 behavior of the HI alpha generations with the mobile, (v) suggestions to enhance the mobile application, and (vi) the importance and suitability of hybridizing NMDG into MSL mobile applications. Thus, to answer the questions, three content experts, the teachers of HI alpha generations, and three academicians were chosen to participate in this study, as shown in Table 1.5 and Table 1.6.

Table 1.3

Preliminary Interview Questions for Content Experts

NO	QUESTIONS	OBJECTIVES
1	What are the biggest challenges for these HI 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 1.4

Preliminary Interview Questions for Academicians

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 in 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 generations context?	
4.	Do you think the NMDG can evoke cognitive ability among HI learners?	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?	
6.	Do you believe existing MSL mobile applications, such as those you described before, should be improved using this rule while building them?	Research Gaps / Problems in existing apps.
7.	Do you think the guidelines need to be reformed because the existing NMDG does not consider HI alpha generations? And do you believe that the existing NMDG for mobile applications is too generic and unsuitable for the HI context?	
8.	Can you explain the guidelines for designing an MSL mobile application for HI? Or do you have other additional policies that come to 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?	
10.	Finally, do you have any more thoughts on improving this research?	

Table 1.5

Content Experts' Profile

No	Job Title	Gender	Age	Years of Teaching Hearing-Impaired	Level of Knowledge Using Mobile Application
1	Teacher	Female	30	10	Good
2	Teacher	Female	39	15	Good
3	Teacher	Female	39	15	Good

Table 1.6

Academicians' Profile

No	Job Title	Gender	Academic Qualification	Research Area	Areas of Expertise
1	Lecturer	Male	PhD Teknologi Maklumat, UUM, Universiti Utara Malaysia	• Human-computer Interaction • Usability • Computers in Education	• Human-Computer Interaction • User Experience • Multimedia in Communication
2	Lecturer	Female	PhD in Multimedia	• Human-computer Interaction	• Interaction Design
3	Lecturer	Female	PhD Pengajaran Multimedia & Teknologi, USM, Universiti Sains Malaysia	• Multimedia Assistive Technology • Game-based Learning Material Development • Instructional Multimedia	• Edutainment (Including Merging Education • Computer Assisted Instruction (CAI) • Games

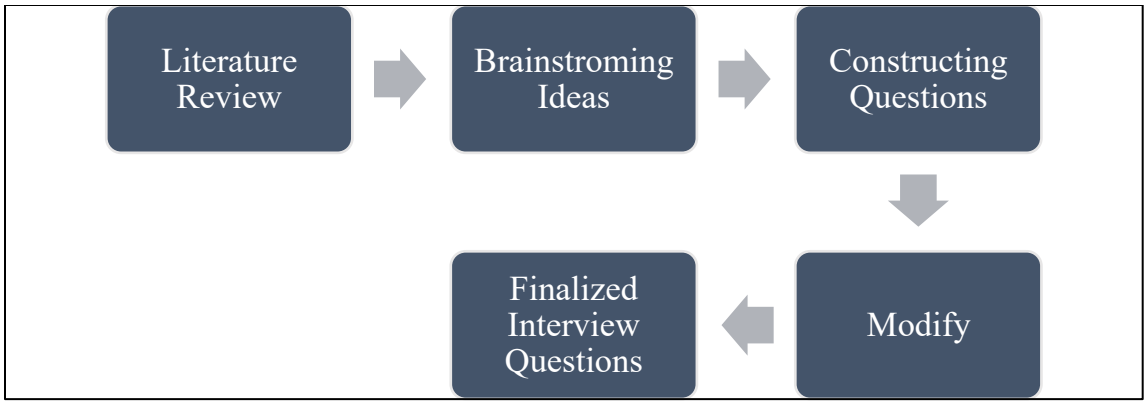


Figure 1.1. Phases in constructing interview questions.

1.4.2 Results and Findings

Table 1.7 depicts the results of the thematic analysis of the interview session with the content experts. According to content expert 1, the HI alpha generations rely entirely on textbooks to learn sign language vocabulary. However, the textbook fails to attract the learners' interest in learning sign language since it lacks a variety of colors and animations. Additionally, content expert 1 also mentioned that most learners have difficulties memorizing and understanding the sign language learning contents.

Table 1.7

Thematic Analysis Content Expert Interview Result

Quotations	**Code**	**Theme**
/…Currently, the students are having problems memorizing and constructing sentences…. /	Learning Problems	Research Gaps
/…Currently, the students are using the learning materials provided by schools, but they find it hard to remember the vocabulary to construct sentences and the sign language associated with it…/	Learning Problems	Research Gaps

Table 1.7 (Continued)

/… The teachers are using PowerPoint to attract the student's interest, but most slow learner students tend to be having difficulties in constructing sentences due to being unable to memorize the vocabulary and the sign …/	Learning Problems	Research Gaps
/… Current teaching materials such as books provided fails to attract the students' interest as they need more colorful and books with cartoon to attract their interest…/	User Interface	Research Gaps
/… 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 vocabulary 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, cartoons, and animation…/	Learning Content	Suggestion

The teachers had taken the initiative to teach the HI learners using PowerPoint slides, according to content expert 2. Since the slides include audio, video, and animations that could attract the HI learners' interest, they enable them to study more effectively. This is because the learners heavily rely on visual aids when learning; hence compelling graphics are necessary to hold their interest. However, the teachers still found that was not enough to aid the learners in memorizing the learning contents since they needed extra exercises to practice independently and increase their memorability. Thus, content expert 2 suggested that it is good for the sign language exercises to be provided with animation or video for the learners since it can enhance their cognitive ability to memorize and understand sign language better.

Next, content expert 3 said that the HI learners are familiar with mobile devices. However, the existing mobile applications do not follow the Malaysian education standard and fail to satisfy the HI learners' needs. As a result, the teachers of the HI learners do not allow them to learn through mobile applications to avoid being confused. In conclusion, most content experts agree that the MSL mobile application should be enhanced by providing an attractive and suitable user interface that attracts learners' needs. Besides, they also suggested that the MSL mobile application should follow the Malaysian education standard for the learning content to avoid the learners from confusion. They also suggested focusing on essential learning, such as ABC and basic conversation.

As for the interview with the academicians, it can be concluded that most of them agreed that hybridizing NMDG in developing MSL mobile applications could evoke the cognitive ability among HI alpha generations. Table 1.8 shows the thematic analysis of the interview session with three academicians. Academician 1 agrees that the suitability of user interfaces is crucial 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 memorability and understandability when capturing information. Academician 1 also stated that a mobile application must satisfy users' needs. If the mobile application fails to meet the user's needs, then the mobile application is a failure.

Table 1.8

Thematic Analysis Usability Expert Interview Result

Quotations	**Code**	**Theme**
/… Functionality and multimedia components are part of the user interface. Functionality, navigation, and how we structure and layout 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 has 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 must see their use of the apps. Perhaps you can assess what is lacking in the system, such as an unattractive user interface, because the user interface might affect the HI attention…/	User Interface	Research Gaps
/… HI, alpha generations need 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
/… I agree that NMDG needs to be reformed by considering the HI context. 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 for evaluating the mobile applications for HI. Thus, the guidelines need to be added by considering HI context…/	NMDG	Research Gaps
/…Yes, I agree that NMDG was able to evoke cognitive ability. But it would be best if you discussed the interface more. 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 recognition rather than recall…/	NMDG	Suggestion

Furthermore, Academician 2 confirms that none of the extensions of NMDG formed has considered the HI alpha generations context. Besides, Academician 2 mentioned that the existing NMDG is too generic and does not consider the HI alpha generations context. However, the NMDG can be extracted to suit the needs of the HI alpha generations context. Thus, new sets of design principles that consider the HI context were formed throughout this study based on the extensions of NMDG made by Kumar (2019).

1.4.2 Research Problem

According to the interview conducted with the content experts who are the teachers of the HI alpha generations, most of them agreed that the existing method of learning sign language was not enough to evoke the cognitive ability among the HI alpha generations. They also stated that the HI alpha generations need attractive and interactive learning methods such as learning through mobile applications with appropriate graphics and user interface design. The content experts also said that the HI alpha generations tend to be attracted to the learning materials composed of various colors, graphics, and videos. Attractive ways of learning could enhance their cognitive ability to understand and memorize sign language vocabulary. Thus, they suggested digitizing the existing textbooks that the learners used for learning at school to have more attractive ways of learning and access it anywhere at any time.

Various MSL mobile applications have been developed and available to support sign language learning among HI learners. However, content expert 1 mentioned that the existing MSL mobile applications' learning content does not follow the Ministry of Education's standard. Besides, it fails to satisfy the HI alpha generations' needs regarding user interface design, such as language provided, graphics, and video. Additionally, Aziz's (2020) research found that the existing MSL mobile applications fail to evoke the cognitive ability among HI people due to the failure to hybridize NMDG in their study. Table 1.9 shows none of their study's existing research on developing MSL mobile applications hybridized NMDG. Then, Academician 2 also agrees that hybridizing NMDG in mobile application development for HI could evoke cognitive ability among them. Thus, it can be concluded that hybridizing NMDG in mobile application development is crucial to stimulating HI learners' cognitive ability.

On the other hand, Kumar (2019) found that the existing NMDG were too generic and unsuitable for mobile application evaluation. Thus, a design guideline reform was implemented by adding three additional guidelines to the current guidelines, but the research does not consider the needs of people with hearing impairment. Thus, a new set of design principles for MSL mobile applications for HI alpha generations based on the extension of NMDG made by Kumar (2019) was formed through this study.

Table 1.9

Existing Application MSL Mobile Application

No	Application Name	Year	Functionalities	Limitations	NMDG
1	3D Sign Language: The Development of Mobile Learning Application	2022	• Learning through categories with video animation • MSL animation hand fingerspelling • Practices and quizzes	• Contents not based on Kod Tangan Bahasa Malaysia syllabus	• Not hybridizing NMDG in the design and evaluation phase.
2	A mobile learning application for Malaysian sign language education	2021	• Learning through categories with videos and audio • Dictionaries for sign language searching • MSL hand fingerspelling practices	• Contents not based on Kod Tangan Bahasa Malaysia syllabus	• Not hybridizing NMDG in the design phase.

Table 1.9 (Continued)

3	E-Learning Approach Using Mobile Apps: Malaysian Sign Language for Dumb and Deaf	2019	• Contents based on KTBM syllabus • Learning categories for alphabet and numbers through static images • Tutorial for greeting, calling names, family, and asking questions through a static image • Video page for learning through website • Quizzes or practices	• Video provided is unreachable • Only available for the English language	• Not hybridizing NMDG in the design phase
4	Mobile Application Dictionary for Hearing Impaired Students	2019	• Contents based on KTBM syllabus • Learning categories for alphabet and numbers through static images • MSL hand fingerspelling	• No video provided for sign language • No practices • Only available in the Malay language	• Not hybridizing NMDG in heuristic evaluation

Table 1.9 indicates that only two applications utilize the formal sign language, the KTBM, for the learning contents, which are applications 3 and 4. At the same time, the remaining are using informal sign language, which is the BIM version. However, these two applications fail to utilize multimedia elements and have usability issues. For example, application 3 provides video learning that was unreachable by the users and only provides learning content in English. While application 4 only provides static images for education and does not provide video learning to attract the users' interest. On the other hand, applications 1 and 2 have good functionalities and maximize the usage of multimedia elements that meet the learners' expectations and needs. However, these two applications fail to follow the local standard of education content.

In the context of hybridizing the NMDG, it can be concluded that none of the existing research on developing MSL mobile applications has hybridized the NMDG, whether in the designing phase or evaluation phase. Hence, a set of design principles were formed throughout this research to fulfill the gaps in this research and act as references for future researchers to adopt in their study when designing and developing MSL mobile applications for the HI learners, especially the HI alpha generations.

1.4.2.1 Research Gaps and Research Questions

Based on the problem background and preliminary study as discussed in the previous section, the following **research gaps** are extracted:

i. Lack of existing MSL mobile applications that hybridize the NMDG.

ii. The existing MSL mobile application needs to be enhanced in user interface and functionality.

iii. Existing NMDG for mobile applications are too generic and do not consider HI alpha generations in their study.

Therefore, this leads to the following **research questions:**

i. Why are the MSL mobile applications' existing design principles inappropriate for the HI alpha generations?

ii. How to validate the design principles of the MSL mobile application for HI alpha generations?

1.5 Proposed Solution

In filling the research gaps, a new set of design principles for the MSL mobile applications for HI alpha generations was constructed based on extensions of the NMDG.

1.6 Research Objectives

The main objective of this research is to form a set of design principles for an MSL mobile application for HI alpha generations based on NMDG. To achieve the main objectives, the specific objectives are constructed as follows:

i. To determine the design principles of MSL mobile application for HI alpha generations through a user-centered design (UCD) approach.

ii. To validate the design principles of the MSL mobile application for HI alpha generations through prototyping, expert review, and user-experience testing.

1.7 Research Scopes

This research focused on forming the design principles of the MSL mobile application for HI alpha generations based on NMDG. Thus, this study is restricted as described in the following point:

i. The research domain area is in the Malaysian environment. Respondents involved are the participants with the homogenous subject in limitation scope.

ii. The working prototype of the MSL mobile application is developed based on a few criteria as follows:

    a) The target user is the HI alpha generations in special schools born after 2010 since the alpha generations are the children known as the 'Digital Generations.'

b) The learning content is sign language vocabulary based on the findings gathered in the preliminary investigation.

This research concerns the formation of design principles based on NMDG rather than the effectiveness of the mobile application for HI learners.

1.8 Research Significance

This study makes several contributions and significance to the body of knowledge and practice. The contribution may be summarized within the following subsections.

1.8.1 Design Principles of MSL Mobile Application for HI Alpha Generations

This study aims to construct a complete set of design principles for the MSL mobile application for HI alpha generations based on the extended NMDG. Future researchers will benefit from these design principles since they can use them as a reference when designing and developing advanced MSL mobile applications for HI learners, particularly the alpha generations. Additionally, this design principle offers a comprehensive heuristics component that will benefit the instructional designer in designing learning materials for HI alpha generations, particularly the sign language learning contents.

1.8.2 Prototype of MSL Mobile Application for HI Alpha Generations

A semi-working prototype of the MSL mobile application for HI alpha generations was designed and developed based on the proposed design principles that the experts have

reviewed through the expert review method. This prototype was designed to validate the proposed design principles through prototyping. It is to ensure that the proposed design principles are reliable and useful. Besides, this prototype was used to validate the proposed design principles through the user experience testing method. The actual users were chosen to experience the prototype and provide helpful feedback through their natural behavior. This will benefit the HI alpha generation users since they can experience the prototype and gain new knowledge. Additionally, the teachers of the HI alpha generations will benefit from this prototype since new interactive methods of teaching sign language were made available to them.

1.8.3 Empirical Findings

The proposed design principles of the MSL mobile application for HI alpha generations were validated through three validation approaches which are expert review, prototyping, and user experience testing. It ensures that the proposed design principles are useful and reliable as a reference for future developers and researchers. The chosen experts from various backgrounds of expertise reviewed the proposed design principles. Then, a semi-working prototype was developed to visualize and validate the proposed design principles through the prototyping method. Next, the prototype was used for validation through the user experience testing method. At the end of this research, a new set of design principles for the MSL mobile application for HI alpha generation was identified and successfully validated.

1.9 Theoretical Framework

This study is based on theories and concepts related to the design of mobile applications for the HI alpha generations. Figure 1.2 illustrates the theoretical and research framework of this study. There are five phases that were carried out, which are (i)problem awareness, (ii)suggestions, (iii)constructions, (iv)validations, and (v)conclusions, as discussed in Chapter 3.

As a kickstart of this study, the content analysis and comparative analysis were carried out to identify the theories and facts related to this study. In the initial phase of this study, which is the problem awareness, three main activities were carried out which are research planning, preliminary investigations, and literature study to identify the research objectives, research scopes, research gaps and problems, and the initially proposed design principles of the MSL mobile application for HI alpha generations based on the extended NMDG. Then, the proposed design principles were constructed through the UCD approach in the construction phase, as discussed in Chapter 4. At this phase, sixteen design principles were successfully identified and achieved the first objective of this study.

Next, the identified design principles of the MSL mobile applications were validated through three validation approaches which are expert review, prototyping, and user-experience testing. At the end of this phase, the design principles were successfully validated and achieved the second objective of this study. Lastly, the research questions and objectives were answered and revisited in the conclusion phase.

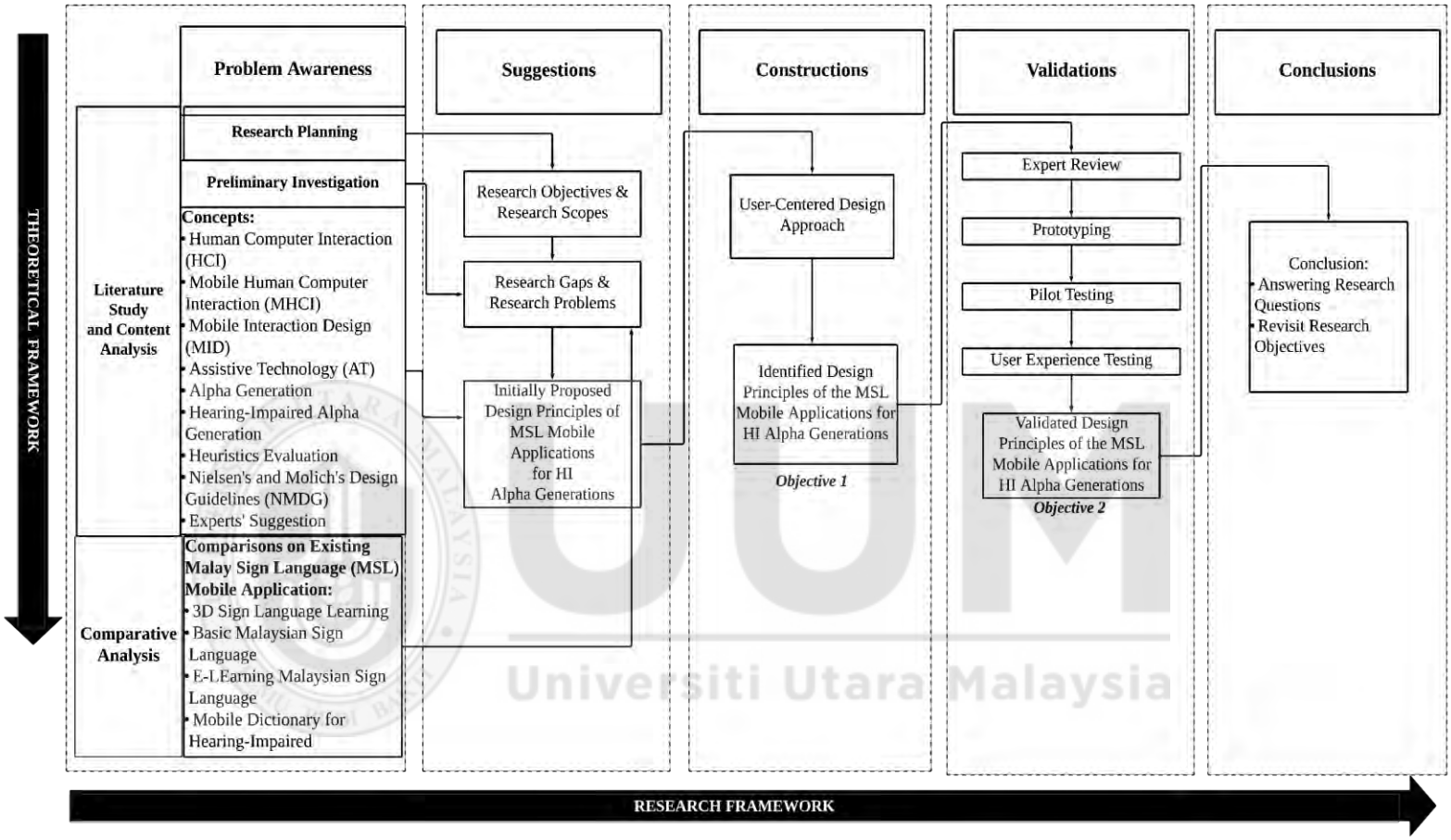


Figure 1.2. Theoretical and research framework

1.10 Operational Terminologies

This section describes the terminologies related to this study, leading to the operational terminologies used commonly throughout this study.

Human-Computer Interaction (HCI)

Human-Computer Interaction (HCI) is a field that studies the relationship and interaction between humans and computer systems or software applications that support people's daily activities (Murtaza et al., 2019). In Addition, the widespread integration of mobile learning platforms into formal and informal learning processes via HCI has resulted in numerous benefits and drawbacks related to technical and educational issues (Pikhart, 2021). Furthermore, the mobile learning platform is increasingly used by younger users, particularly the alpha generations, for educational purposes. As for this study context, the alpha generations were identified as the critical user. Hence, developing mobile learning applications is the best way to attract the users' attention.

Mobile Human-Computer Interaction (MHCI)

The communication between the users and the software embedded in the mobile devices is called Mobile Human-Computer Interaction (MHCI) (Memon et al., 2017). The software designed and developed for mobile devices was named mobile applications. Due to their efficiency and ease of use, mobile devices may soon supersede the desktop and laptops.

Mobile Interaction Design (MID)

The task of designing the mobile application technology is known as mobile interaction design (MID). Developing the technology for people with disabilities (PWDs) are challenging task, particularly for the alpha generations, since the designers need to decide on the best design approach that is reliable to the users' conditions (Du & Tekinbas, 2020). Thus, practicing the user-centered design (UCD) approach is suitable for eliciting the requirements, developing the prototype, and evaluating the design to ensure it meets the users' needs and expectations (Du & Tekinbas, 2020). As for the context of this study, the UCD process was adopted in designing the MSL mobile applications for HI alpha generations to ensure the mobile applications meet their needs.

Assistive Technology (AT)

Assistive technology is software and hardware designed to be used by people with disabilities (PWD) (Dhanjal & Singh, 2019). In this study, the MSL mobile application is intended to assist the HI learners, particularly the alpha generations, in interactively learning sign language.

Hearing-Impaired Alpha Generations

Hearing-impaired people have limitations in their hearing that leads to a slight, medium, or total loss of hearing (Baglama et al., 2018). In this study, HI born after 2010 with limitations in their hearing were the main subject.

Malay Sign Language (MSL)

Malay Sign Language (MSL) was developed based on Malay-based words and dialects to facilitate communication between HI individuals in Malaysia and society (Palfreyman, 2015). As for the context of this study, the MSL was chosen to be adopted in designing the learning content to follow the standards enforced by the Ministry of Education Malaysia as suggested by the content experts.

Heuristics Evaluation (HE)

A heuristic evaluation (HE) is a usability inspection method for computer software that helps identify usability problems in the user interface (UI) design. It specifically involves evaluators examining the interface and judging its compliance with recognized usability principles (Jeddi et al., 2020). There are various types of HE, such as cognitive walkthroughs and NMDG. However, for this study context, NMDG was chosen to be adopted.

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

Nielsen's and Molich's Design Guidelines (NMDG) is one of the types of HE. According to Kumar (2019), this method includes several evaluators to evaluate and observe the user interface and provide feedback and comments based on the design guidelines. As for this study context, this method was chosen as it is crucial to evoke the cognitive ability among HI learners.

1.11 Thesis Structure

This thesis consists of eight chapters. The entire contents of each chapter are described as follows:

Chapter 1: Introduction

As an introductory chapter, this chapter describes the background of the study and elaboration on the current issues that lead to the motivation of the study, research gaps, and the research problem. Then, the result of the preliminary investigation is also discussed, guiding the formation of research objectives and questions and the research scopes, contributions, and operational terminologies used in this study.

Chapter 2: Literature Review

This chapter comprises a systematic review to discuss this study's concepts, theories, and approaches. An exhaustive review of literature on the evolution of existing Nielsen and Molich's Design Guidelines (NMDG) and the comparative analysis of the existing Malay Sign Language (MSL) mobile applications were extensively discussed within this chapter, as well as the theories and concepts related to designing MSL mobile application for hearing-impaired (HI) alpha generation. The review highlights the need to form the design principles for MSL mobile applications for HI alpha generations based on NMDG.

Chapter 3: Research Methodology

This chapter describes the overall research process required to achieve all the objectives stated in Chapter 1. Iterative Triangulation Methodology (ITM) and Design Science Research Method (DSRM) were adopted using the qualitative approach for the whole research process. Each phase was further discussed with the activities within this chapter.

Chapter 4: Construction of the Design Principles of the MSL Mobile Application through UCD

This chapter clearly explains how Nielsen's and Molich's Design Guidelines (NMDG) were used to construct the new set of design principles for the Malay Sign Language (MSL) mobile application for hearing-impaired (HI) alpha generations. The user-centered design (UCD) approach was adopted to construct the design principles. The experts and representatives of actual users were involved throughout this phase. All the activities involved were extensively discussed in this chapter.

Chapter 5: Expert Review

The previous chapter briefly explained the tasks involved in constructing the design principles of the Malay Sign Language (MSL) mobile applications for hearing-impaired (HI) alpha generations based on Nielsen's and Molich's Design Guidelines (NMDG) that have been extended. The chosen experts reviewed and validated the constructed design principles using the expert review approach covered in this chapter.

Chapter 6: Prototyping the MSL Mobile Application

The design principles that have been reviewed and validated by the experts then must be transformed into a working prototype. Prototyping makes sure that the proposed design principles are useful and reliable. So, this chapter discussed each process involved in developing the MSL mobile application.

Chapter 7: User Experience Testing on the MSL Mobile Application

In achieving the second objective of this study, the prototype of the MSL mobile application was evaluated and validated through a user experience testing approach. Two cycles of direct observation methods were carried out to observe the behavior of the selected subjects towards the prototype. Also, the testing procedures provided for this study are discussed in this chapter.

Chapter 8: Conclusion

Finally, Chapter 8 discusses the findings of this study by answering all the research questions and objectives and concluding the whole work in this study, particularly in considering the implication of the design principles of the MSL mobile application to the body of knowledge, theory, and practical as well as recommendations for future directions of the study.

1.12 Chapter Summary

HI alpha generations are the children born after 2010 who have difficulties in hearing and cannot utilize their hearing organs in learning. Thus, MSL mobile applications were developed to support the HI learners in sign language learning as sign language is one of the mediums for communication. However, from the preliminary studies, it was found that the existing MSL mobile applications fail to hybridize the NMDG as it is essential to evoke the cognitive ability among HI learners and fail to satisfy the HI learners' needs in terms of user interface and functionalities. Besides, past research shows that the existing NMDG does not consider the HI alpha generations context. Thus, a set of design principles for MSL mobile applications for HI alpha generations based on NMDG were formed through the UCD process and validated design principles through prototyping, expert review, and user experience. Lastly, this research will benefit many people, such as future researchers, teachers, and HI learners. This research provides a manual for developing and designing mobile applications for HI people, particularly the HI alpha generations.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter comprises a systematic review to discuss this study's concepts, theories, and approaches. An exhaustive review of literature on the evolution of existing Nielsen and Molich's Design Guidelines (NMDG) and the comparative analysis of the existing Malay Sign Language (MSL) mobile applications were extensively discussed within this chapter, as well as the theories and concepts related to designing MSL mobile application for hearing-impaired (HI) alpha generations. The review highlights the need to form the design principles for MSL mobile applications for HI alpha generations based on NMDG.

2.2 Human-Computer Interaction (HCI)

Human-computer interaction (HCI) is a field that studies the interaction and relationship between people and computer systems, including the application software that people use daily (Zhu, 2020). There are three main components of HCI which are (i) **users,** individuals who use the systems or software, (ii) **computers,** technology used by the users, such as the application, and (iii) **interaction,** communication between the users and the computers (Al Mahdi et al., 2019).

The main goal of the HCI concept is to design and construct a system that is effective and safe to use by the users and lower the barriers between the users and the computerized

systems (Murtaza et al., 2019). Additionally, the effectiveness of the computer systems can be measured from two distinct viewpoints, as explained by Yong-hao (2020) below:

i. **Usability Goals:** Users can use the interactive systems independently and find them convenient. Then, it can enhance the users' engagement with the systems, offer a high degree of pleasure, and allow users to have a better experience accomplishing activities in their everyday lives.

ii. **User Experience:** It refers to subjective feelings describing the interaction between users and the systems. Their actions and interactions with the systems will reveal their level of satisfaction.

Due to the technology advancement, the requirement of the technology users is more demanding, reflected in the deployment of numerous mobile devices that can perform multiple tasks, small sizes, and are easy to carry, such as tablets and smartphones (Al Mahdi et al., 2019). Furthermore, the growth of HCI has impacted several fields, notably education, where most physical-based learning has been replaced by digital-based learning employing mobile devices (Grudin, 2012). Hence, the interaction between users and mobile devices was known as Mobile Human-Computer Interaction (MHCI), which was discussed briefly in the following section. However, according to Al-Hunaiyyan (2021), the concepts of MHCI are similar to the HCI concepts in those users still interact with the computer system; the difference is that the computer system is embedded in the mobile devices.

2.3 Mobile Human-Computer Interaction (MHCI)

The COVID-19 pandemic outbreak has hastened the growth of mobile device usage. People are using mobile devices for various purposes, including education. According to Samad (2021), the Malaysian government has introduced the Online Distance Learning (ODL) initiatives because of the school closures due to the pandemic. Under these initiatives, the learners must attend classes virtually through their devices. This is to avoid physical contact between the teachers and learners. However, most learners prefer to attend online classes through their mobile devices, such as laptops or tablets, as it is more convenient for them and allows them to do so whenever and wherever they want (Al Mahdi et al., 2019). Thus, the new interaction trends between users and mobile devices occurred, referred to as 'Mobile Human-Computer Interaction (MHCI).'

MHCI is the interaction or relationship between the users and the application software embedded in mobile devices such as smartphones (Memon et al., 2017). The application software embedded in the mobile devices is known as the mobile application. Due to the small size and convenience of carrying them, mobile devices are increasingly popular in the community, particularly in the alpha generations (Al Mahdi et al., 2019). In Addition, their efficacy and ease of use may soon supersede desktop and laptop computers (Memon et al., 2017). According to Du (2020), designing the mobile application or software will include the concepts of Mobile Interaction Design (MID), which are covered in detail in the next section. Since this study considers the mobile application context, MHCI concepts were used to construct the design principles.

2.4 Mobile Interaction Design (MID)

Designing mobile applications is challenging, particularly for children with disabilities (Du & Tekinbas, 2020). The designers must ensure that the application's design is suitable, satisfies the needs of users with various disabilities, and fits those needs (Ribeiro et al., 2018). This is to ensure that the users can benefit from the application.

On top of that, the MID concepts should be one of the critical components to be highlighted since this research is focused on developing the design principles of the MSL mobile application for HI alpha generations. This is to ensure that the design principles may guide future researchers to design and develop suitable mobile applications for HI learners and satisfy their needs as well as their expectations. Furthermore, the mobile application used by people with disabilities (PWDs) is a part of the 'Assistive Technology' discussed in the following section.

2.5 Assistive Technology (AT)

Currently, technology has been part of the necessity in accelerating human life, including for people with disabilities (PWDs). The life of PWDs has been impacted due to the rapid evolution of modern technological developments. The technology used by the PWDs is also known as Assistive Technology (AT). According to the Individuals with Disabilities Education Act (IDEA), AT can be defined as "any item, piece of equipment, or product system that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (Dhanjal & Singh, 2019, p. 205). AT can be classified into hardware-

based, software-based, and prosthetic implants based on disabilities. Besides, it covers many assistive, adaptive, and rehabilitation devices designed explicitly for PWDs (Soetan et al., 2021).

As for the context of this study, the HI alpha generations were chosen to be highlighted. According to Dhanjal (2019), approximately 466 million people worldwide with hearing impairments based on the World Health Organization (WHO) data. Most HI alpha generations inherited the disabilities from their parents. Besides, National Center on Accessible Instructional Materials (2013) stated that using AT in disabled learners needs to be considered to support their learning and provide a comfortable learning environment. Thus, this study will benefit more HI people in the future based on the trends reported. There are three categories of AT designed explicitly for HI people, which are Assistive Listening Devices (ALD), Augmentative, and Alternative Communication (AAC and Alert System), as shown in Table 2.1 by Dhanjal (2019).

Table 2.1

Categories of Assistive Technology (AT).

Categories of AT	Description
Assistive Listening Devices (ALD)	Amplify weak audio signals or waves for hearing-impaired people in prominent areas such as airports where the information is conveyed through audio. Objective and subjective evaluations of the speech enhancement methods improve the quality and intelligibility of speech signals.

Table 2.1 (Continued)

Augmentative and Alternative Communication (AAC)	People with hearing impairment or language disability use gestures or sign language, computer-generated 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, and vibration to alert hearing-impaired people when a specific event occurs. Fire alarms, baby-cry alarms, and doorbell have lost their hearing capability. Then Gesture language is the first and most preferable for them. A normal person hardly understands the gestures, so various sign language recognition and learning tools focus on how to teach and understand sign language to a normal person.

Source: Dhanjal (2019)

ALC is computer-generated speech that generates text by scanning the sign language contents, such as a sign language detector. There are two types of ALC available, which are aided ALC and unaided ALC. Aided ALC is the devices the HI people use to support communication, such as MSL mobile applications. In contrast, unaided ALC is the communication that occurs through hand gestures, body language, or facial expressions to convey information to the speakers. The last category of AT is the alert system. An alert system is a vibration or amplified sound that alerts the HI in certain emergencies. Fire alarms and doorbells are examples of alert systems. As for the context of this study, the MSL mobile applications can be seen as the aided types of ALC as the HI people use the mobile applications to help them communicate with society.

Next, Table 2.2 shows the examples and parameters of the AT that can support the HI people in communication by Dhanjal (2019). According to the technology used, there are nine AT parameters highlighted, which are glove-based sign language recognition, 3D devices to recognize sign language, speech recognition and noise cancellation, web-based services, network-based teletypewriter (TTY) wearable technology, and visual alert systems. As for the context of this study, MSL mobile applications can be classified as the sign language learning application parameter. It is a device-based application that develops for the HI people to learn and practice sign language.

Table 2.2

Parameters and Examples of AT

AT Parameters	Example of AT
Gloves-Based Sign Language Recognition	**American Sign Language (ASL)** fingerspelling recognition glove translates ASL alphabets to English text and synthesizes output based on body sensor.
3D Devices to Recognize Sign Language	**VisualComm Kinect 3D** sensor-based two-way communication system trained 370 daily Chinese sign words that can translate text to Chinese and vice versa.
Sign Language Learning Application	**SmartSignPlay** tablet-based game application developed to learn and practice ASL for hearing-impaired people.
Speech Recognition and Noise Cancellation	**SmartHear** android mobile application includes features of transmitter or receiver and noise reduction techniques.
Web-Based Service	**SportSign** web-based application for the hearing-impaired to entertain and understand news in Sign Language.

Table 2.2 (Continued)

Network-Based	Bluetooth technology-based phone as an assistive device to route the environment noise-free audio signal directly to a cochlear implant processor or hearing aid.
Teletypewriter (TTY)	A special type of telephone provides features to type a text message instead of speaking with a small LCD screen.
Wearable	**LaneMate** implemented a car sensing system using an ultrasonic proximity sensor to detect the distance and an analogue sound sensor to calculate the loudness of the car's horn.
Visual Alert Systems	**Deaf Assistance Digital System (DADS)** is aware of dangerous situations by implementing speech and sound recognition engines.

Source: Dhanjal (2019)

On top of that, mobile applications have become more prevalent in the HI community as the world evolves towards digitalization. Besides, learning through mobile applications has become a new trend and a significant part of learning in the HI community, particularly in the HI alpha generations (Jeyaranjani & Nesarani, 2018). The digital generation that often uses mobile devices is known as the HI alpha generation, described in detail in the next section.

2.6 Alpha Generations

People born within a specific year with the same cultural and political influence have been linked to the same environment known as generations (Augusto et al., 2018). There are five stages of human generations described by Augusto (2018) in Table 2.3.

Table 2.3

Stages of Generation

Stages of Generation	**Years of Born**
Baby Boomers	1946-1964
Gen-X	1965-1977
Table 2.3 (Continued)	
Gen-Y	1978-1989
Gen-Z	1990-2010
Alpha Generation	**2010-Present**

Source: Augusto et al. (2018)

Table 2.3 shows that the alpha generations are the children born after 2010 and might be the children of generations Y, Z, or both. They are also known as the 'Digital Generation' as they have been exposed to digital technology such as smartphones, tablets, and laptops since they were small (Ziatdinov & Cilliers, 2022). Digital technology is widely employed in many countries as a teaching tool for alpha generations. For instance, Brazil has established the "Mobile Integral School," which will incorporate this discipline into the curriculum starting in 2017 and intends to foster the growth of imaginative and inquisitive learners capable of using technology to make solutions (Augusto et al., 2018, p. 11).

Accordingly, to support and provide the HI alpha generations with a creative learning environment, MSL mobile application was introduced to them. It gives the HI alpha generations interactive ways of learning and assists them in utilizing the technology for

educational purposes. Consequently, this study focuses more on the HI alpha generations, further discussed in the next section.

2.7 Hearing-Impaired (HI) Alpha Generations

Hearing impairment affects one or both ears, leading to hearing loss below 90 decibels (Downs & Yoshinaga-Itano, 1999). At the same time, the HI alpha generation can be defined as the children born after 2010 and having limitations in utilizing their hearing organ that leads to slight, medium, or total loss of hearing (Baglama et al., 2018). Furthermore, the HI alpha generation may be having issues with verbal communication due to hearing impairments, which has prevented them from adequately acquiring their mother tongue's speaking and literacy dimensions (Baglama et al., 2018).

Accordingly, Aziz's (2020) research shows that most HI alpha generation also have cognitive disabilities due to hearing impairment, making them difficult to understand and memorize the learning contents, particularly the sign language content. Besides, Meghana (2020) also mentioned that the HI alpha generation also has difficulties in their learning, such as being unable to understand the grammar and syntax of the language, difficulty communicating with the teachers, and inability to convey their thoughts due to their limitation of vocabularies and failure to catch the complete conversation. Thus, to overcome these problems, they need to learn basic sign language skills and vocabulary before entering school to lead a typical learning environment for children without hearing impairment. Various types of sign language are available worldwide, depending on the

country. As for the context of this study, Malay Sign Language (MSL) was chosen to be adopted since it is the HI learners' mother tongue of language. Further details of the MSL are discussed in the following section.

2.8 Malay Sign Language (MSL)

Sign language is one of the most used tools by the HI worldwide that acts as a communication medium between them and society. They use sign language to convey their thoughts through hand gestures, body language, and lip-sync when the writing and typing are too complex (Bala & Song, 2020). According to Baglama (2018), sign language is a method that does not use voice to convey words but only with the hand sign representing a series of words or letters to express the speakers' thoughts to the listeners.

Various versions of sign language are available worldwide based on the cultures and dialects, such as American Sign Language (ASL), British Sign Language (BSL), and Pakistan Sign Language (PSL). In Malaysia, there are two versions of sign language available, which are formal sign language named 'Kod Tangan Bahasa Malaysia (KTBM)' and informal sign language named 'Bahasa Isyarat Malaysia' (Kamarudin & Hussain, 2019). According to Chong (2018), KTBM is a standard sign language with Malay spoken language imposed by the Ministry of Education Malaysia to be used by the HI alpha generation at school. Thus, it is crucial for the HI alpha generation in Malaysia to clearly understand sign language to have a better learning experience.

Besides, various ways of learning sign language are available, such as through mobile applications. Numerous MSL mobile applications have been developed and are currently available in the market to support HI learners in mastering sign language. However, Siong (2021) mentioned that the existing MSL mobile application fails to satisfy the users' expectations due to usability issues and a lack of functionalities. Besides, Aziz (2020) also stated that the existing MSL mobile application fails to evoke the cognitive ability among HI learners. Thus, ensuring that the designed mobile application is evaluated thoroughly is crucial. To ensure the mobile applications meet the users' expectations, Aziz (2020) mentioned that the mobile applications need to be assessed by the users or the experts to solve the usability issues.

On the other hand, various methods are available to evaluate the usability of the system or products. As for the context of this study, the usability heuristics evaluation was chosen as it is one of the most popular methods used by the researchers due to its effectiveness and efficiency. The usability heuristics evaluation concepts are further discussed in the next section.

2.9 Usability Heuristics Evaluation

Usability heuristic evaluation is a method that allows the practitioners or/and researchers in the HCI field to evaluate and verify the system interface is usable based on a set of principles (Jeddi et al., 2020). Different researchers have adopted various types of heuristic principles across different research in the evaluation process, such as NMDG and Cognitive

Walkthrough. According to Paz (2018), the most recognized heuristic in the literature is the NMDG because it is a cost and time-saving method. On the other hand, Aziz (2020) also suggested hybridizing the NMDG in designing mobile applications, particularly for HI learners, as it could evoke the cognitive ability among the HI learners. Hence, the NMDG was chosen to be adopted within this study as suggested by the previous researchers, as this study considers the context of mobile applications for HI learners.

2.9.1 Nielsen's and Molich's Design Guidelines (1990)

In 1990, there were nine guidelines formed by Jakob Nielsen, as shown in Table 2.4. These heuristics were first published in the article "Improving a human-computer dialogue" by Rolf Molich and Jakob Nielsen in Communications of the ACM, March 1990.

Table 2.4

Nine NMDG by Jakob Nielsen in 1990

No	Heuristics	Description
1	**Simple and natural dialogue**	The dialogue should not contain irrelevant needed information. Every unrelated piece of information in a conversation competes with the relevant information, lowering their relative prominence. All data should be presented in a logical and natural order. In the example, the questions on an online form are shown in the same sequence as they are on a paper form, and the compasses apps must appear the same as in real life.
2	**Speaks the user language**	Instead of using system-oriented terms, the interaction should be communicated clearly in words, ideas, and concepts with which the user is familiar. In the example, it is good to show the error messages as "This page does not exist due to errors. You can proceed report to www.example.com" instead of "Error 404".

Table 2.4 (Continued)

3	**Minimize user memory load**	The short-term memory of the user is limited. The user should not have to recall information from one dialogue segment to the next. When possible, instructions for using the system should be visible or easily accessible. Instructions that are too complicated should be simplified.
4	**Be consistent**	Users should not have to guess what different words, situations, or actions signify. When possible, one user action should always be able to accomplish a particular system action. Coordination between subsystems and major independent systems with shared user populations is frequently referred to as consistency. In the example, in an organization, all systems use the exact login words, such as "username" (not "user-id") and "password" (no access key). Using the same login screen for all systems is much better.
5	**Provide feedback**	The system should constantly update the user on what is happening by promptly giving timely feedback. In the example, after a password is changed, an app confirms: "Password successfully changed"
6	**Provide clear marked exits**	A system should never lock users in situations where there is no way out. Users frequently select system functions by accident, necessitating the presence of a clearly defined "emergency escape" that allows them to quit the unwanted state without having to go through a lengthy discussion. For example, a user presses the Exit button by accident. The application gives you the option to "Save and exit," "Exit without saving," or "Cancel" before departing. The "Cancel" button is a safety feature.
7	**Provide shortcuts**	The elements that make a system easier to learn – such as lengthy dialogues and a limited number of entry fields on each display – are typically inconvenient for a seasoned user. To accommodate beginner and experienced users, clever shortcuts — undetected by the novice user – are frequently included in systems.
8	**Provide good error messages**	Defensive, precise, and constructive error messages are ideal. Defensive error messages always blame the problem on system flaws and never point the finger at the user. Detailed error messages give the user precise information about the problem's cause. Constructive error messages show the user helpful advice about what to do next.
9	**Error prevention**	An intelligent design that prevents a problem from developing in the first place is even better than effective error messages. For example, before permanently deleting a file, a file management system asks the user for confirmation.

Source: Kumar (2019)

2.9.2 Nielsen's and Molich's Design Guidelines (1994)

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 2.5. Thus, there are ten design guidelines that have been formed.

Table 2.5

Ten NMDG by Nielsen and Molich's in 1994

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 users to identify the apps' elements quickly.
3	**User control and Freedom**	The use of text and icons which are intuitive and easily recognizable enables users to quickly identify and comprehend elements on the app.
4	**Consistency and Standards**	Allow individuals to go to different menus with ease and the ability to exit and enter other selections of the application quickly.
5	**Error preventions**	Mobile learning applications have 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 users' 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 to both novice and expert users; hence should be able to adjust to a person's rhythm.

Table 2.5 (Continued)

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 support and guidance in identifying elements in the app, give examples to perform tasks, and assist in the completion of crucial tasks

Source: Kumar (2019)

2.9.3 Nielsen's and Molich's Design Guidelines (2019)

In 2019, Kumar found that the existing NMDG is not very effective 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 2.6.

Table 2.6

13 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**	Identify the apps' elements quickly based on the standard education

Table 2.6 (Continued)

3	**User control and Freedom**	The use of text and icons which are intuitive and easily recognizable enables users to quickly identify and comprehend elements on the app.
4	**Consistency and Standards**	Allow individuals to go to different menus with ease and the ability to exit and enter other selections of the application quickly.
5	**Error Preventions**	Mobile learning applications have 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 the error.
7	**Flexibility and Efficiency of Use**	Minimizing users' 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 to 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 support and guidance in identifying elements in the app, give examples to perform tasks, and assist in completing crucial tasks.
11	**Selection driven commands**	Users are engaged with choice rather than typing or feeding data, menu, or list selection; the use buttons and user control interface are used instead.
12	**Content organization**	The content needs to highlight key learning objectives, some elements of the content organization are content would need to be optimized to fit on one screen, and multiple screens can be used to display content if the content is large.
13	**Visual representation**	Use of pictures, icons, screen objects, sound, text color, background color, and animations to help the user learning process

Source: Kumar (2019)

2.9.4 Summary Evolutions of Nielsen's and Molich's Design Guidelines

Table 2.7 shows the evolution of NMDG from 1990 until 2019. The table shows that the latest design guidelines consist of 13 design guidelines formed by Kumar (2019) for mobile application evaluation. In 1990, the NMDG was created by Jakob Nielsen with nine design guidelines and was reformed by him by adding one additional design guideline in 1994. The initial purpose of the design guidelines was to evaluate the system software. However, Kumar (2019) has reformed the design guidelines to make them suitable for mobile application evaluation, but it does not consider the HI alpha generation context. Thus, this study has formed the design principles based on NMDG that considers the HI context.

Table 2.7

Evolution of NMDG (1990 – 2019)

No	Nielsen's and Molich's Design Guidelines / Year	1990	1994	2019
1	**Visibility of the system status**	√	√	√
2	**Match between the system and real world**	√	√	√
3	**User control and Freedom**	X	√	√
4	**Consistency and Standards**	√	√	√
5	**Error Preventions**	√	√	√
6	**Recognition Rather than Recall**	√	√	√
7	**Flexibility and Efficiency of Use**	√	√	√
8	**Aesthetics and Minimalist Design**	√	√	√
9	**Help users recognize, diagnose, and recover from errors.**	√	√	√
10	**Help and Documentation**	√	√	√
11	**Selection driven commands**	**X**	**X**	√

Table 2.7 (Continued)

12	**Content organization**	**X**	**X**	√
13	**Visual representation**	**X**	**X**	√

2.10 Existing MSL Mobile Applications

Malay Sign Language (MSL) mobile applications were developed to support HI learners, especially the alpha generation, in enhancing their cognitive abilities in sign language learning. Various MSL mobile applications were designed through model development and prototype design. The MSL mobile applications can be described as follows:

2.10.1 3D Sign Language: The Development of Mobile Learning Application (2022)

The 3D sign language mobile application by Jamaluddin (2022) is an application that was developed for HI children and general users who are people without hearing impairment. This application uses 3D animation to move to sign language. Besides, this application also includes multimedia elements such as graphics, audio, texts, animation, and videos, as shown in Figure 2.1.

Figure 2.1. Learning contents

This application provides sign language learning by category, including learning by alphabets, numbers, and basics, as shown in Figure 2.2. It also offers quizzes to access the learners' understanding of the sign language learning contents, as shown in Figure 2.3. The sign language contents were designed based on the Bahasa Isyarat Malaysia (BIM) contents, the non-formal sign language. This study adopts the ADDIE (Analysis, Design, Develop, Implementation, and Evaluate) model as a method for developing the application. Each phase is connected to each other and crucial to producing the best application.

Figure 2.2. Learning by category

Figure 2.3. Quizzes and video learning

During the evaluation phase, the evaluation was conducted with close contacts, family, and friends. They are required to use the application to evaluate the effectiveness of the applications and how they affect the users. Few questions were asked to the respondents to gain their feedback. Thus, no experts and actual users were involved in evaluating and validating the usability of the applications. Although the applications were designed attractively with the good use of multimedia elements and functionalities, the applications are still unable to be considered suitable for the HI learners since the actual users and the experts were not involved in the evaluation stages to evaluate the usability issues and how it impacts the real users.

2.10.2 Basic Malaysian Sign Language Mobile Application (2021)

Education through mobile applications has grown ubiquitously, particularly sign language learning. Sign language is a communication tool between the HI people and the community. Thus, it is beneficial for both parties to know and learn basic sign language. However, one of the problems faced by the community in learning basic sign language is the accuracy of the learning contents. Thus, the main purpose of developing this application is to provide accurate basic sign language learning for the users to learn sign language.

Research by Mohamed (2021) applies the ADDIE design method, and there are five phases involved: analysis, development, design, implementation, and evaluation. Within the analysis design phase, the background of the potential users was studied, such as their behavior and demographics. Besides, the project's scope, background, objectives, and

problems were also discussed within this phase. During the development phase, the application and software were studied and chosen based on the needs of the studies. Thus, this study chooses Adobe Animate CC, Adobe Photoshop, Adobe Animate Software, and ActionScript 3.0 to be used in developing this application. This ensures that this application could attract the users' intention towards the application's interface.

The application prototype was designed according to the users' needs and wants during the design phase. Figure 2.4 shows the categories of learning provided by this application, such as learning alphabets, numbers, greetings, basic conversation, and quizzes. This application was available in Malay, and the learning contents only focused on the Bahasa Malaysia syllabus. Figure 2.5 shows the learning interface for the alphabet and numbers learning category. The fingerspelling was shown in a static image associated with the texts.

Figure 2.4. Menu

Figure 2.5. Learning content for alphabet and numbers learning categories

Next, this application also provides video learning for the greetings learning category. Figure 2.6 shows an example of an interface for greetings learning. The videos were associated with the texts to describe the learning contents further.

Figure 2.6. Video learning for greetings learning categories

As for the basic conversation learning categories, the applications provide two different learning content categories: ‘Ahli Keluarga’ and ‘Negeri-Negeri Di Dalam Malaysia.’ No sign language learning is provided; the learning contents are also associated with the texts and static images, as shown in Figure 2.7. Then, this application also provides additional learning features named ‘Kuiz Menguji Minda’ to assess the learners’ understanding of the learning contents, as shown in Figure 2.8.

Figure 2.7. Basic conversation learning

Figure 2.8. Quizzes

The next phase is the implementation phase, where the testers or the developers test the prototype that has been designed. The application was downloaded onto the smartphone and tested to ensure the application was well-functioning. The last phase of the ADDIE method is the evaluation phase. The researchers choose the respondents to try out this application within this phase. The respondents were selected from public and high school students. It can assess the app's effectiveness based on user feedback during this phase. The

researchers distributed a questionnaire with 13 questions to 35 people ranging from 19 to 45 years old regarding feedback. As a result, nearly 80% of respondents said they would like to learn sign language using the apps, indicating that the public is already aware of communicating using sign language. Nearly 87% of respondents agreed that this application is appropriate as a new learning medium. The remaining 12.5%, or five respondents, were neutral, while none disagreed. As a result, it can be concluded that the overall response has been positive. This is because most people today learn sign language regardless of age.

In conclusion, this application was not developed specifically for the HI people, but it was developed for both parties who are the HI people and the people without hearing impairment. Thus, the researchers do not include the actual users who are the HI people in the evaluation stage to evaluate the application to ensure it meets the HI people's needs. In Addition, the evaluation does not hybridize any design guidelines to assess the usability issues. Thus, evaluating mobile applications based on the design guidelines is crucial to ensure usability.

2.10.3 E-Learning Malaysian Sign Language (2019)

E-learning Malaysian Sign Language by Haron, Samad, and Yusof (2019) was an application that was designed and developed to enhance the learning process of HI people by providing better learning experiences. This application aims to assist the HI people in having convenient learning experiences by having the flexibility of learning style. Learning

through mobile applications enables HI learners to access the learning material anywhere and anytime. Besides, this application also targets the people without hearing impairment to provide new knowledge, particularly the community, regardless of age, to ease the communication between the HI people and society.

This spiral model of the life cycle method was chosen to develop the E-learning MSL mobile application. It contains four main stages: planning, risk analysis, engineering, and evaluation. Then, Figure 2.9 shows the home page of the E-Learning Mobile application. This application only focuses on English education learning. This application provides five activities: learning, tutorial, video, and quiz. This application also provides the history of MSL for additional knowledge.

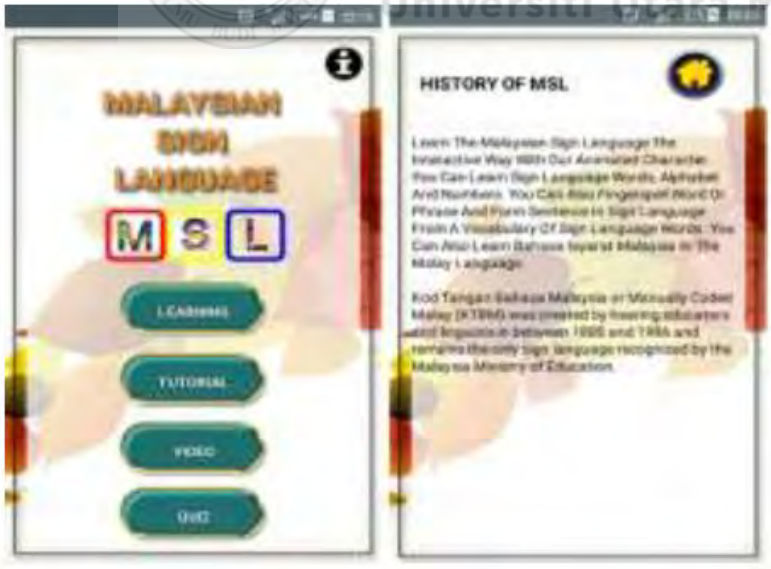


Figure 2.9. Main pages and history of msl page

Then, Figure 2.10 shows the page for the ‘Learning’ category. It provides two types of learning which are Alphabet learning and Numbers learning. When the users click on one of the learning categories, it will directly go to the learning pages that contain the fingerspelling static images, as shown in Figure 2.10.

Figure 2.10. Learning category pages for alphabet and numbers

Next, the second learning section highlighted by this application is ‘Tutorial,’ which contains the basic words for learning. Figure 2.11 shows the ‘Tutorial’ page covering four learning categories: greeting, calling names, family, and asking questions. The tutorial section provided the learner with static images of how to perform sign languages.

Figure 2.11. Tutorial page

Figure 2.12 shows the third learning section, which is learning through video. The video page contains a video for virtual MSL learning that can be accessed through the link provided. However, the link provided was unreachable; it might be removed or broken.

Figure 2.12. Video learning

Lastly, the last learning section would be the Quizzes, as shown in Figure 2.13. The users can choose to start the quizzes from two categories: alphabet and numbers. The users' names displayed the score at the end of these quizzes.

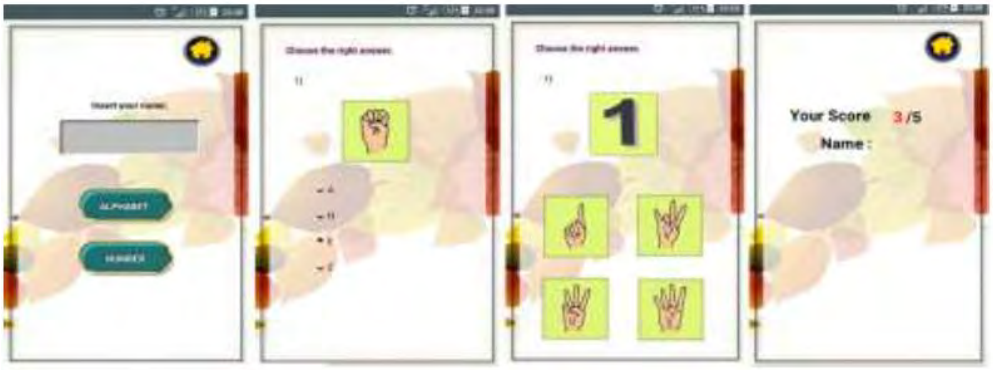


Figure 2.13. Quizzes section

The learning contents of this application were good and matched with the standard of KTBM, the formal sign language that the Ministry of Education Malaysia has established for learning purposes. However, as suggested by the researchers, it is good to have additional multimedia elements such as video, audio, and animation as it could attract the users' attention, particularly the children. This application only provides text and static images. Thus, the multimedia elements are crucial to be adopted in designing the MSL mobile applications to enhance the quality of learning. Hence, it could evoke cognitive ability among the HI learners.

2.10.4 Mobile Dictionary for Hearing-Impaired (2019)

A dictionary is a tool that provides meanings of words, synonyms and antonyms, and information on spelling, pronunciation, and different forms of words. According to Mohd Suhaimi (2019), technological innovation has enabled digital dictionaries by integrating multimedia components such as graphics, pictures, animation, and video. Thus, this research aims to provide MSL digital dictionaries for HI children to access and search for

words corresponding with the sign. Moreover, searching for a word online takes shorter time than using a printed dictionary. In brief, it can be said that a digital dictionary benefits the HI community by making word search easier and faster.

There are five phases involved in designing and developing this mobile application which can be described as follows:

i. Analysis

The analysis phase helps identify the necessary specifications for the interface design and learning technique that must be included in this application. Any specifications needed were captured in this phase by analyzing data gathered in phase one, including interviews with teachers and a literature review. As a result, the analysis phase identified important interface design and learning module attributes required to move on to the next phase.

ii. Design

The conceptual model was used in this phase to create an appropriate interface design. During the design phase, a conceptual model can assist a designer in avoiding unnecessary factors. The application was built using dual coding, cognitive load, and multimedia cognitive theory during the design phase. There are eight main learning modules provided named ‘Abjad’, ‘Angka’, ‘Anggota Badan’, ‘Buah-Buahan’, ‘Sayur-Sayuran’, ‘Ucapan’ dan ‘Suku Kata’. This mobile application focus on the Bahasa Malaysia syllabus contents.

iii. Development

The output from the previous phase was used as an input for this phase. Building several interface designs, developing the navigation button, and organizing each topic was part of the development process to ensure that users understood the content and could easily manage the application. The application's use of color and text size was based on human interactions for mobile application principles. This application focused on early education, so it was appropriate for preschool and first-year HI students.

iv. Prototyping

The prototype phase focused on implementing the dictionary's mobile application, which included integrating the interface, the module, and the submodule. The mobile app was designed to work with the Just in Mind Prototype app, installed on mobile devices.

v. Testing and Evaluation

Expert feedback improved the application during the testing and evaluation phase. The number of experts involved in evaluating applications was critical during this phase. Most researchers recommend having three to five experts in one area of expertise involved in consumerism testing to cover 80% of the market (Nielsen, 1990; Turner, Lew, 2006; Virzi, 1992). Two to three experts may be used if an expert has expertise in two fields or is a double expert. Experts can find 60% of consumer issues in one area, making them 2.7 times better than novice users and 1.5 times better than experts (Nielsen, 1994).

As a result, only four double experts in human-computer interaction, sign language, or software development participated in this study. The quality of the users' experience when interacting with the prototype was important to measure, so this phase included evaluation, divided into two parts: interface design evaluation. Next, the findings can be divided into the development of mobile applications and the evaluation results. As for the development of the application, a prototype was designed that contained 13 main screens, which are the welcoming screen as shown in Figure 2.14, four home page screens, alphabet screen, number screen, primary human body part screen, animal screen, fruit screen, vegetable screen, greeting screen, and noun screen. Three theories were used in the design phase: cognitive load theory, dual coding theory, and multimedia cognitive theory.

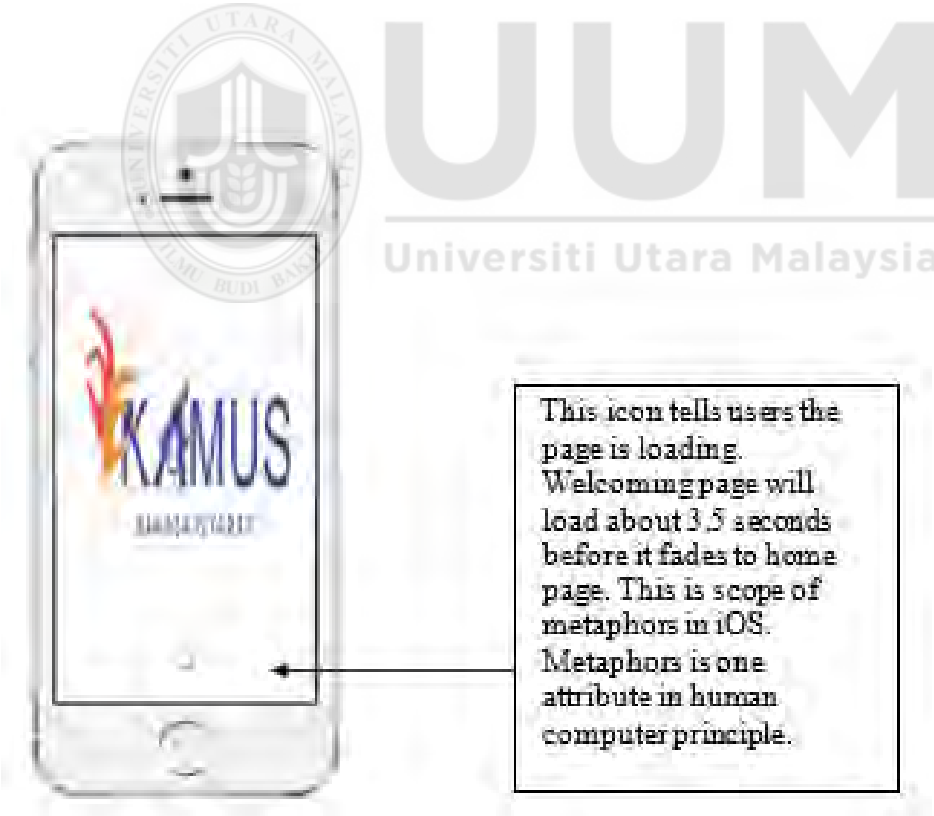


Figure 2.14. Welcoming screen

According to cognitive load theory, only a limited amount of information must be presented at any given time. This theory was used to develop the modules in this study. Figure 2.15 shows some examples of modules that utilize this theory. There was only one object associated with the texts on one screen. Furthermore, the dual coding theory explains how users process information using verbal and visual means. By clicking on the alphabet and listening to the audio, users could hear the pronunciation of the alphabet and words. This was appropriate for HI with a low hearing rate. Students could also view the sign language by selecting the "Isyarat Tangan" button. In the mobile application, the home button was added. This was done following the human-computer interaction principle, which encourages users to take shortcuts (Hussain, 2018).

Figure 2.15. Learning page

The content validity index (CVI) assessed the experts' findings. A set of questionnaires was designed with two sections (Part A and Part B), which evaluated interface design and learning design. The results of the experts' review were summed up, and CVI values of 0.91 for interface design features and 0.83 for learning design were discovered. As a result, the content validity index (CVI) value has been accepted. The comments of the experts based on the applications are shown in Table 2.8.

Table 2.8

Suggestions from Experts

No	Suggestions from Experts	Reasons
1	The font needs to change from times new roman to century gothic	• Deaf students easy to understand with century gothic font
2.	Alphabet with uppercase needs to change to lowercase.	• Pre-school and year one students start to learn with lowercase
3.	Color the object	• To make the learning process more enjoyable.
4.	Add the element to search for the category	• More user friendly
5.	Increase time display for sign language when button 'isyarat tangan' is clicked	• Information display can be absorbed effectively

Source: Mohd Suhaimi (2019)

In conclusion, this research may shift teaching from traditional learning to a more technologically friendly environment. However, this application only provides static images for the learning materials and sign language fingerspelling. No video learning or

animation is provided to attract the learners' attention, particularly the HI alpha generation. Thus, this application can be enhanced by utilizing more multimedia elements in designing mobile applications.

2.10.5 Comparative Analysis of the Existing MSL Mobile Applications

Given the rapid growth of mobile technologies, Attewell (2005) advises comparing mobile technologies that were created at least three years prior to the year the research is conducted. Thus, there were only four applications developed in the past three years that are still on the market and were compared as tabulated in Table 2.9. Five categories were compared which are multimedia elements, learning contents and functionalities, syllabus language, learning standard, and hybridizing NMDG.

Table 2.9

Comparative Analysis Result

No	Name of Application	Author	Multimedia Elements Provided					Learning Contents and Functionalities	Syllabus Language	Learning Standard	Hybridizing Nielsen and Molich's Design Guidelines
			Video	Audio	Animation	Graphics	Text				
1	3D Sign Language Learning	(Jamaluddin, 2022)	/	/	/	/	/	Alphabet, numbers, basic conversation, and quizzes	Malay	Bahasa Isyarat Malaysia (BIM)	X
2	Basic Malaysian Sign Language	(Mohamed et al., 2021)	/	/	X	/	/	Alphabet, numbers, basic conversation, and quizzes	Malay	Bahasa Isyarat Malaysia (BIM)	X
3	E-Learning Malaysian Sign Language	(Haron, 2019)	X	X	X	/	/	Alphabet, numbers, sign tutorial (greeting, calling name, family, asking questions), and quizzes.	English	Kod Tangan Bahasa Malaysia (KTBM)	X
4	Mobile Dictionary for Hearing-Impaired	(Mohd Suhaimi et al., 2019)	X	/	X	/	/	Alphabets, numbers, body parts, vegetables, fruit, animal, nouns, and greetings.	Malay	Kod Tangan Bahasa Malaysia (KTBM)	X

From Table 2.9, it can be concluded that none of the latest MSL mobile applications models has hybridized NMDG in designing or evaluating the MSL mobile applications. As for the multimedia elements, only 3D Sign Language Learning applications design the application by utilizing all the multimedia elements, including the animation, using the 3D approach in designing the application. Most of the applications only provide video, audio, texts, and static images for the sign language learning contents except for E-Learning Malaysian Sign Language. The application only provides texts and static images for learning, while Mobile Dictionary for Hearing-Impaired only provides audio, static images, and texts.

Next, for the learning content, most applications provide similar learning content: learning through categories, the alphabet, numbers, and basic conversations. Besides, most applications offer additional features such as quizzes to assess the learners' understandability and memorability of the learning contents, except for Mobile Dictionary for Hearing-Impaired. As for the syllabus language, all applications focus on the Bahasa Malaysia learning contents except for E-Learning Malaysian Sign Language, which focuses on English. This is because, in Malaysia, the HI people are crucial to mastering the Bahasa Malaysia sign language better than the English sign language since Bahasa Malaysia is the Malaysian language's mother tongue. Next, for the learning standard, two applications (3D Sign Language Learning and Basic Malaysian Sign Language) use informal sign language learning, which is Bahasa Isyarat Malaysia (BIM), and two applications (E-Learning Malaysian Sign Language and Mobile Dictionary for Hearing-

Impaired) use the formal sign language learning which is Kod Tangan Bahasa Malaysia (KTBM).

In conclusion, most applications offer goods that use multimedia elements and functionalities. Still, none of the applications has hybridized NMDG in designing and evaluating the mobile applications as it is important to evoke the cognitive ability among HI people. Thus, a prototype of MSL mobile applications was designed and developed based on the design principles formed based on the NMDG for HI alpha generations.

2.11 Chapter Summary

This chapter clearly described that the Mobile Human-Computer Interaction (MHCI) is a part of Human-Computer Interaction (HCI) that enables the communication between users and mobile or system applications. The technology designed for people with disabilities (PWDs), which is known as Assistive Technology (AT), is an example of HCI. This study focused on the alpha generation group of users. It highlighted the hearing-impaired (HI) alpha generation as the primary users. According to the World Health Organization (WHO), the trends of the HI people were estimated to be leveled up. Thus, this study will benefit more HI people in the future. In Malaysia, the learners, particularly the alpha generation, utilize mobile learning applications.

Accordingly, various Malay Sign Language (MSL) mobile applications were developed to support the HI alpha generation learning sign language. To develop suitable mobile applications, the usability issues need to be evaluated to ensure the users have a good experience using the applications. Thus, this study chooses a heuristics evaluation based on Nielsen and Molich's Design Guidelines (NMDG) since it could evoke the cognitive ability among HI people, especially alpha generation. However, no existing NMDG was designed by considering the HI context. Thus, a new set of design principles was intended for HI alpha generation MSL mobile applications based on the existing NMDG. Lastly, the previous study analyzes four existing MSL mobile application models. None of the existing MSL mobile applications has hybridized the NMDG. Thus, this study proposes a new MSL mobile application prototype that hybridizes the NMDG.

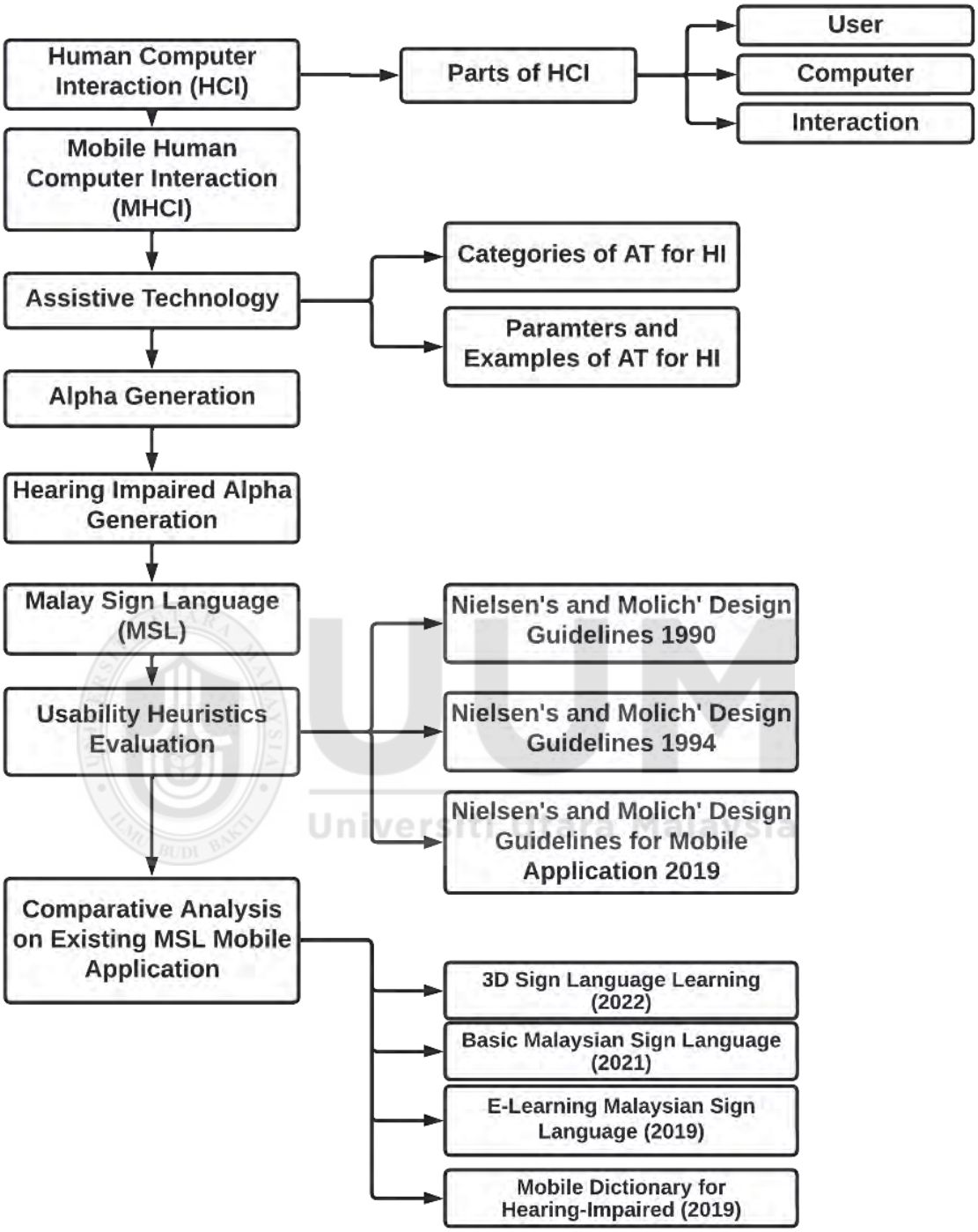


Figure 2.16. Summary of chapter 2

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Overview

This chapter briefly describes the overall research process required to achieve all the objectives stated in Chapter 1. Iterative Triangulation Methodology (ITM) and Design Science Research Method (DSRM) were adopted using the qualitative approach for the whole research process. Each phase involved was discussed extensively within this chapter.

3.2 Rationale for Adopting Qualitative Approach

Qualitative research uses a multimethod and naturalistic approach to observe the research's subjects in their natural habits and routines to acquire insight into the phenomenon related to the study (Aspers & Corte, 2019). The case study, personal experience, introspective, life narratives, interview, observational, historical, interactional, and visual tests are examples of empirical materials in qualitative research to explore ordinary and complex events and meanings in subjects' life (Ugur, 2020). In this context, this research focuses on the phenomena of hearing-impaired (HI) alpha generations, as mentioned in Chapter 1. Accordingly, this approach is relevant to be conducted within this study because:

i. The primary subjects of this research are children with hearing impairment. Thus, they need a less complex and naturalistic approach to gain insight into their behavior and emotions while participating in this study.

ii. Alpha generation with hearing impairment are the children that need extra attention towards their behavior and emotions, as they provide meaningful and valuable data. Besides, the qualitative approach ensures the richness of data by observing the subjects' behavior and natural habits.

iii. This approach has been found in past research involving the alpha generation with hearing impairment as the primary subjects, such as Westby's (2020) and Baglama's (2018) research.

Furthermore, the triangulation method was adopted to ensure that all the research's objectives were fulfilled, as proposed by numerous studies, and thorough discussions were held in the following sections.

3.3 Triangulation Method

To avoid fundamental biases arising from using a single technique or a single observer, the triangulation approach was conducted to increase the reliability and validity of the study findings by combining the theories, methodologies, or observers in a research study (Noble, 2019). Additionally, this method can be applied in quantitative and qualitative studies to provide a better insight into complex human behavior by utilizing various approaches to verify the validity of findings (Flick, 2018).

According to Flick (2018), Denzin (1978) proposed three different forms of triangulation methods: data triangulation, researcher triangulation, and methodological triangulation. In this study, all triangulation methods were adopted and are briefly discussed below:

3.3.1 Data Triangulation

Data triangulation refers to compiling information from various periods, places, and people to produce a better and more in-depth explanation of occurrences. Denzin (1978) recommended breaking down data triangulation into subtypes and evaluating it at various dates (to study time differences), locations (for comparative research), and with various people, according to Flick (2018). This method of triangulation was used in the context of this study to evaluate the Malay Sign Language (MSL) mobile application. The prototype was tested simultaneously on two groups of HI alpha generations (3-partial hearing loss and 3-total hearing loss). Then, to express their feelings about the application, they need to provide overall feedback using the rating system, which was further discussed in Chapter 7.

3.3.2 Researcher Triangulation

The main goals of researcher triangulation are to compare the perspectives, ideas, and analysis findings of various researchers working on the same topic. This method commonly referred to as **"member checking"** involved using a range of researchers in the same study to collect various observations in a specific area while allowing the researchers to debate their points of view to lessen the biases. This approach tries to evaluate multiple

researchers' impacts on problems and solutions. In this study, two observers participated in observation sessions to observe how the subjects interacted with the prototype. The instruments such as video cameras and recording sheets were used to record the sessions. It is to increase the validity and reliability of data to avoid biases.

3.3.3 Methodological Triangulation

Methodological triangulation is the most popular and common method that numerous researchers adopted. It involves the combination of methods to obtain more complete and detailed data about the phenomenon of the study. If multiple independent measures produce the same results simultaneously, they can give a more accurate picture of the leadership phenomena. Within this study, the subjects' observation and rating methods were done to gain insights into their feelings and level of satisfaction with the prototype. The methods were combined to achieve more detailed feedback from the subjects who are children with hearing impairment. Thus, they need a more natural and visual method in approaching them for feedback.

On the other hand, the iterative triangulation method (ITM), which demands the iteration of processes, is therefore employed in this study context to avoid the biases of results. Further details as explained in the following sections.

3.4 Rationale for Adopting Iterative Triangulation Method (ITM)

As discussed with the examples of the triangulation methods in the previous sections, this study can be accomplished by adopting the iterative triangulation method (ITM). The rationale for adopting the ITM can be described as follow:

i. To overcome the biases arising from the complex and dynamic qualitative data using only one method, observer, and theory.

ii. Provide better evidence and increase the validity, credibility, and reliability of the interpretation of research with a qualitative approach.

iii. Provide meaningful and comprehensive explanations of the findings from qualitative data by using an in-depth cross-different method.

iv. Caters all research phases and provides research outcomes relevant to the expectations of studies.

v. Has been found in past research such as Natow (2019) and Hankebo (2018).

Consequently, the Design Science Research Method (DSRM) was adopted within this study and further discussed in the following section.

3.5 Rationale for Adopting Design Science Research Method (DSRM)

Design Science Research Method (DSRM) was adopted within this study as it allows iteration to earlier activities in particular phases which are the “evaluation phase, or communication back to define objectives or design and development, depends on the

reason of cycling back" (Venable et al., 2016, p. 3). The rationale for using the DSRM method can be described as follows:

i. It consists of two primary activities, which are build and evaluate.

    a. Build – Process of constructing the MSL mobile application.

    b. Evaluate – Process of determining the performance of MSL mobile application.

As for this research, the MSL mobile application that the actual users and experts will evaluate through user experience testing.

ii. Provides a systematic process to design a practical MSL mobile application.

iii. Enable iteration in particular phases, such as the design or evaluation.

Then, the following sections explain the overall research process in detail based on the illustration of the research method.

3.6 Phases in Research Methodology

Based on the above elaboration, this study adopted three parts which are (i) theoretical study, (ii) development, and (iii) empirical. All of them were integrated and required the iteration process. Furthermore, five phases of DSRM were employed, which are (i) problem awareness, (ii) suggestion, (iii) construction, (iv) validation, and (v) conclusion.

Figure 3.1 illustrates the summary of the methodologies involved and the connections. The main goal of this study is to construct a new set of design principles for the MSL mobile application for HI alpha generations based on Nielsen and Molich's Design Guidelines (NMDG). Thus, to accomplish the objectives of this study, a sequence of steps was involved. Still, they are not always executed in line as this study requires an iteration process to increase data validity and reliability.

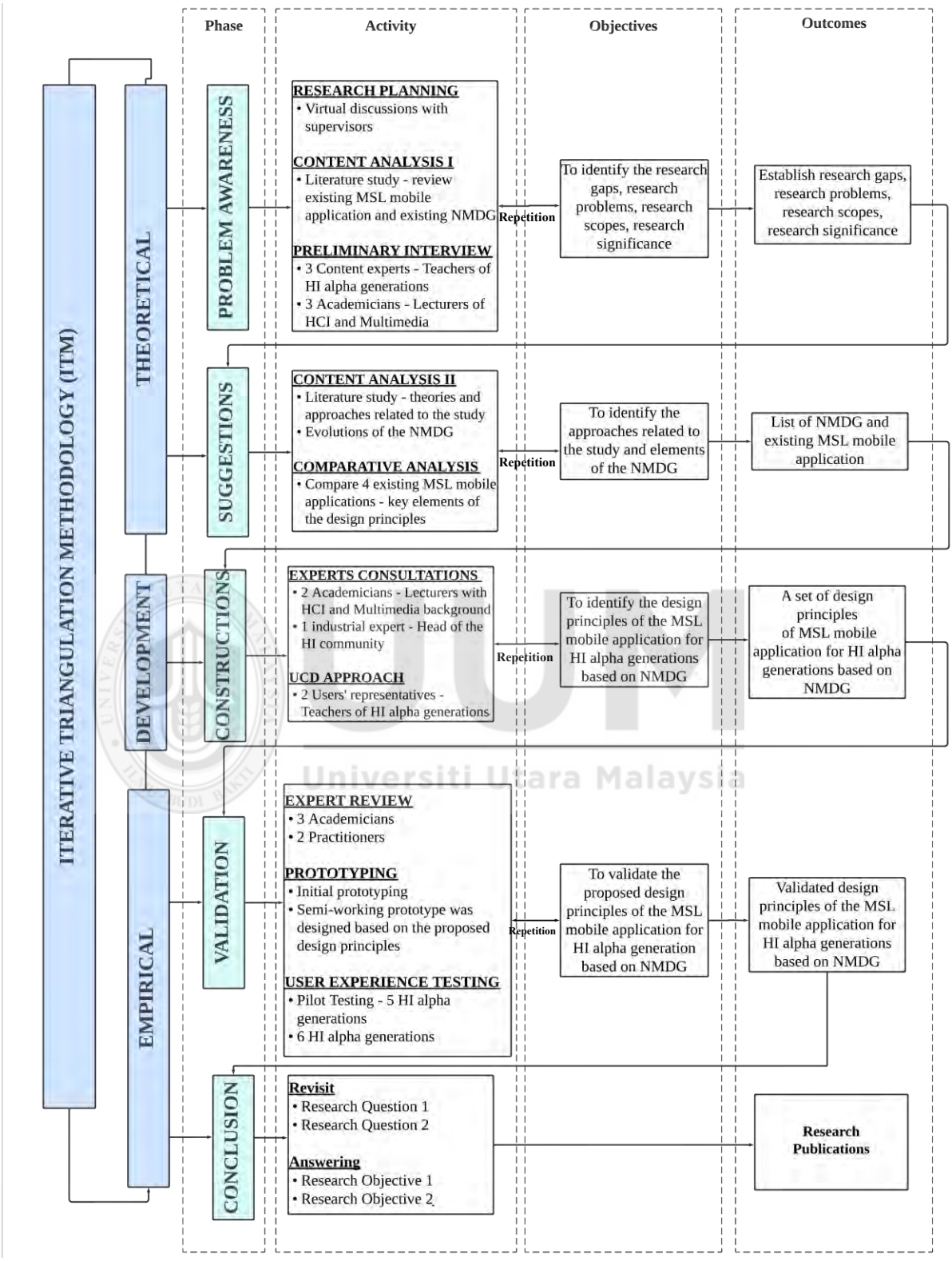


Figure 3.1. Summarization of research methodology

3.6.1 Phase 1: Problem Awareness

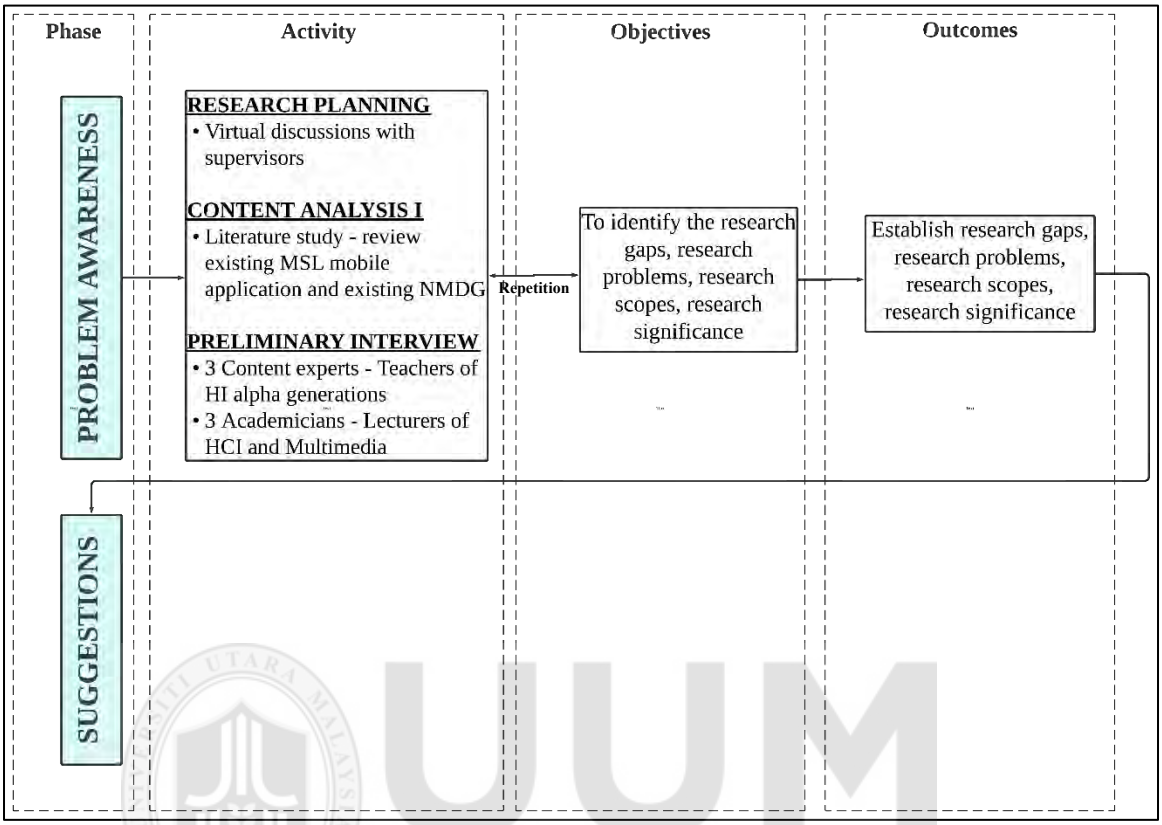


Figure 3.2. Phase 1: Problem awareness

This study was started with research planning, literature studies, and preliminary interviews with academicians and content experts to identify the research problems, gaps, and significance of this study, as discussed in Chapter 1. Figure 3.2 illustrates the initial phase of this study, which is problem awareness, and leads to the second phase, the suggestion. These phases were iterated until the objective of this phase was achieved. Further descriptions were discussed as follows:

3.6.1.1 Research Planning

As a kickstart of this study, several virtual group discussion sessions have been conducted with the supervisors to discuss the issues that led to this study briefly. The research questions, objectives, significance, and scope were discussed during the discussions described in Chapter 1.

3.6.1.2 Content Analysis I

The content analysis was done through literature studies to enhance this study's research problems, gaps, and scopes. Comprehensive and systematic literature studies were performed to seek information through secondary sources such as journals, articles, proceedings of international and local conferences, and books. The contents of the data can be in multiple forms, such as tables, figures, and texts.

Consequently, the latest past research related to the existing MSL mobile applications and the evolutions of the NMDG were reviewed. The rationale for reviewing the existing MSL mobile applications is to confirm the research problems related to the usability issues affecting the users' satisfaction. At the same time, the rationale for reviewing the NMDG is to ensure the research gaps this study can fill. The critical information and facts gathered from these sources are outlined in tables and extensively discussed in Chapter 1. This helps in gaining better insights into the problems to be solved. Based on the key issues, two preliminary interview sessions were conducted with the content experts and academicians, further discussed in the following subsection.

3.6.1.3 Preliminary Interview

Six preliminary interview sessions were conducted with six experts (three academicians and three content experts). The academicians are the lecturers with more than ten years of teaching experience in Human-Computer Interaction (HCI) and multimedia designs, while content experts are teachers of the HI alpha generations with more than five years of experience teaching sign language in government schools for disabled children. The experts were approached with different purposes. As for the content experts, the purpose of approaching them is to gain insight on current practices used by the teachers to teach the HI alpha generation and problems faced by them in teaching as well as how they see the mobile application could help them in teaching and support their students in learning, while the academicians were approached to gain insight into the reliability of forming the design principles based on the NMDG.

Accordingly, two sets of open-ended interview questions were designed for both experts. The semi-structured interview sessions were conducted virtually with the experts through the Google Meet platforms. The interview results were analyzed using the thematic analysis method to gain insight into the common themes and patterns of the data. Both interview questions and findings are discussed in detail in Chapter 1. This process was iterated until the gaps and needs of the research were identified. At the end of this phase, the study's research problems, gaps, objectives, scopes, and significance were identified in Chapter 1.

3.6.2 Phase 2: Suggestions

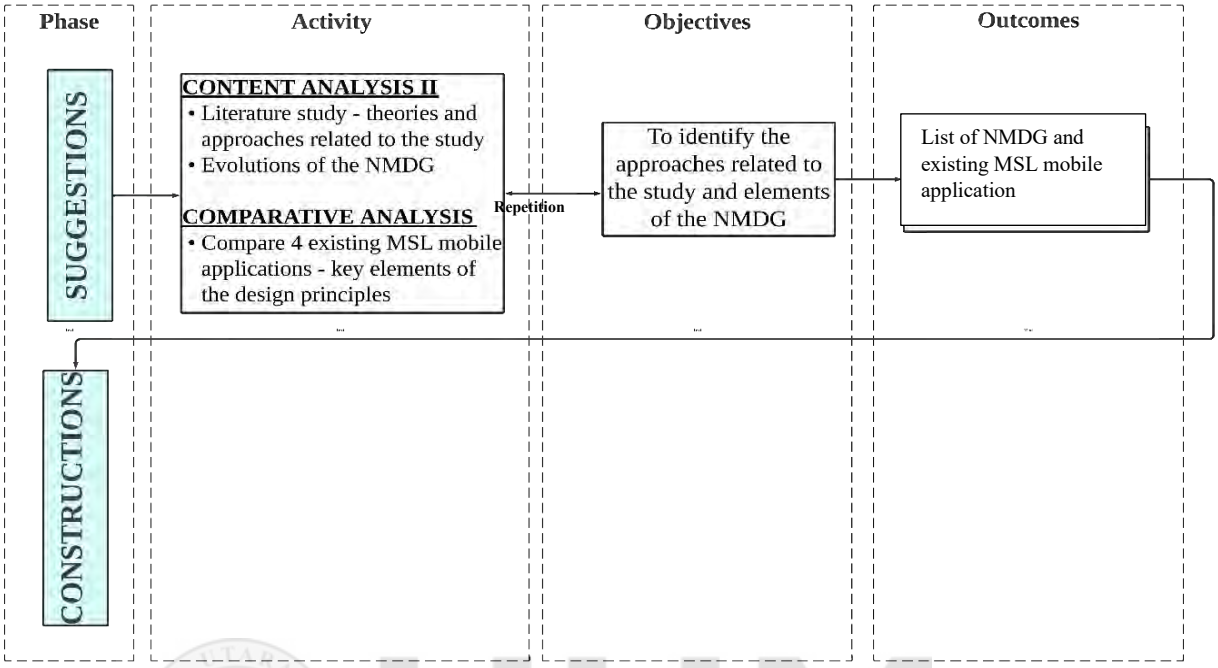


Figure 3.3. Phase 2: Suggestions

Having identified the research problems, objectives, gaps, scopes, and significance of this study, move on to the second phase, suggestions. In this phase, content analysis II and comparative analysis were conducted to identify the approaches related to the study and the NMDG. This phase was iterated until the objective was achieved. At the end of this phase, the NMDG and the existing MSL mobile applications were identified, along with the theories and facts related to this study. Figure 3.3 shows the activities involved in phase two and is further discussed as follows:

3.6.2.1 Content Analysis II

Content analysis II was conducted to gain better insight into this study's theories, facts, information, approaches, and methods. Extensive literature reviews were carried out, as discussed in Chapter 2. Four existing MSL mobile applications were further analyzed, and the suggestions made by the previous researchers were considered. Then, the evolutions of the NMDG were extensively discussed. The results were presented in graphics, tables, and texts. Thus, the comparative analysis was made and discussed in the following sections.

3.6.2.2 Comparative Analysis

A comparative analysis has been conducted to identify the special elements based on the existing MSL mobile applications that have been designed. Four existing MSL mobile applications were chosen and compared. Each application was based on the multimedia elements (video, audio, animation, graphics, text), learning contents and functionalities, syllabus language, learning standard, and status of hybridizing the NMDG. The elements were extracted and tabulated in Table 2.8 (Chapter 2). At the end of this phase, the elements of the NMDG and existing MSL mobile applications were identified. The users' representatives extensively discussed them in the next section, which is the construction phase.

3.6.3 Phase 3: Construction

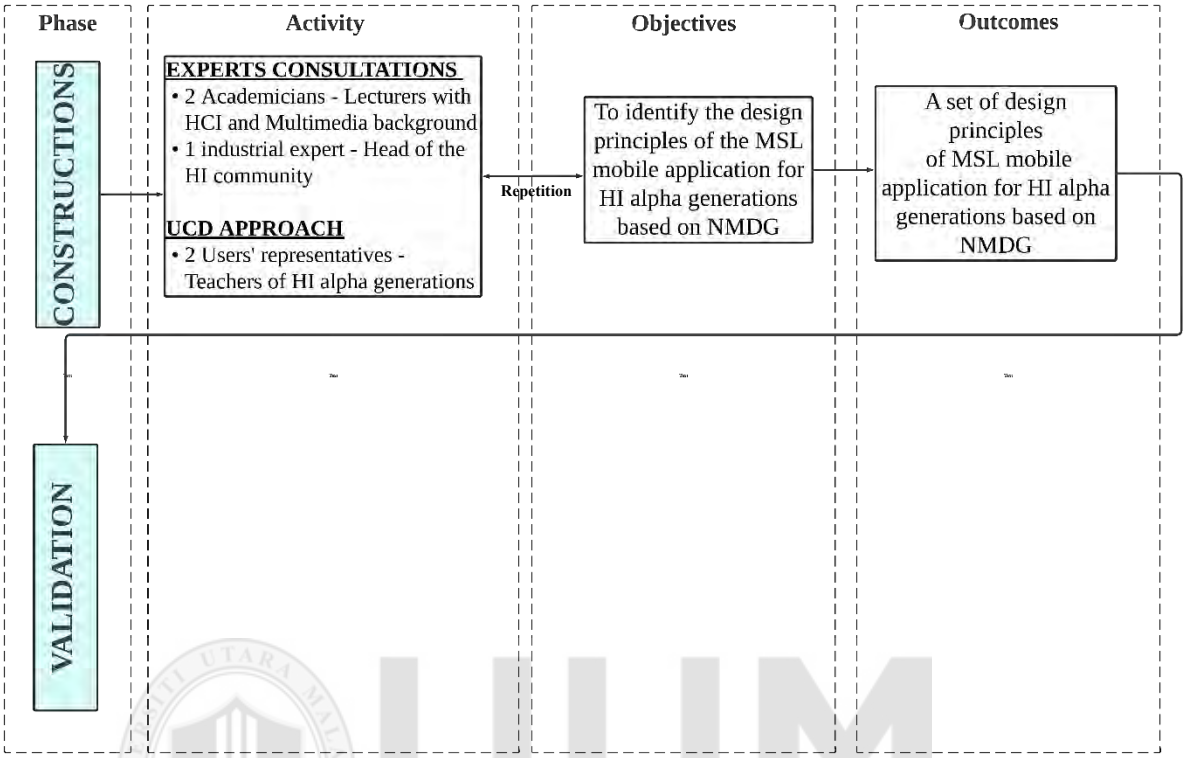


Figure 3.4. Phase 3: Constructions

Figure 3.4 shows the third phase, which is the construction phase. This phase is a crucial part of this study where the design principles of the MSL mobile applications were constructed and identified. The activities involved were extensively discussed as follows:

3.6.3.1 Experts' Consultations

At this stage, three experts with different backgrounds were involved in reviewing and suggesting the design principles of the MSL mobile application for HI alpha generations based on the extended NMDG. Two experts who are academicians and one expert who is an industrial expert were chosen. The NMDG and the existing MSL mobile applications

that have been identified in the previous phase were discussed with the experts. At this phase's end, five design principles were initially proposed and discussed in Chapter 4. To confirm the suggested design principles of the MSL mobile application, the users' representatives were chosen to be involved and further discussed in the next section.

3.6.3.2 User-Centered Design (UCD) Approach

The User-Centered Design (UCD) Approach has been utilized. In this case, the actual users must be involved to ensure the identified proposed design principles meet their needs and expectations. UCD is a process in which the requirements and limitations of the actual users of the products are given total concentration at each level of the process. The feedback and comments from the actual users are then used to decide on the design of the end products. Table 3.1 shows a list of principles described by ISO standards to ensure the design is user centered.

Table 3.1

Fundamental principles of UCD.

No	Items
1	The design is based on a clear understanding of users, tasks, and the environment.
2	Users are involved throughout the development process.
3	The design is developed based on user-centered evaluation.
4	Iterative process.

Table 3.1 (Continued)

5	The design addresses the user's experience.
6	The design team includes multidisciplinary skills and perspectives.

In this study, the users' representatives were chosen to represent the actual users. The rationale for involving the users' representatives is due to the limitations of the actual users, who are children with hearing impairment. Thus, they need fewer complex ways of approaching them. Two users' representatives were chosen. Accordingly, weekly online discussions were conducted with the users' representatives through the Google Meet platform to construct and discuss the proposed design principles. The lists of the NMDG and the initial low-fidelity prototype were the main instruments. This phase was iterated until the final design principles were confirmed. As a result, sixteen design principles were proposed for the MSL mobile application for HI alpha generations based on twelve NMDG. Hence, one of the objectives of this study was achieved as the proposed design principles have been successfully identified. A detailed explanation of the process involved in determining the design principles is described in Chapter 4. Next, in achieving the second objective of this study, the proposed design principles were validated through three validation methods which are expert review, prototyping, and user experience testing. Extensive discussions were made in the following section.

3.6.4 Phase 4: Validation

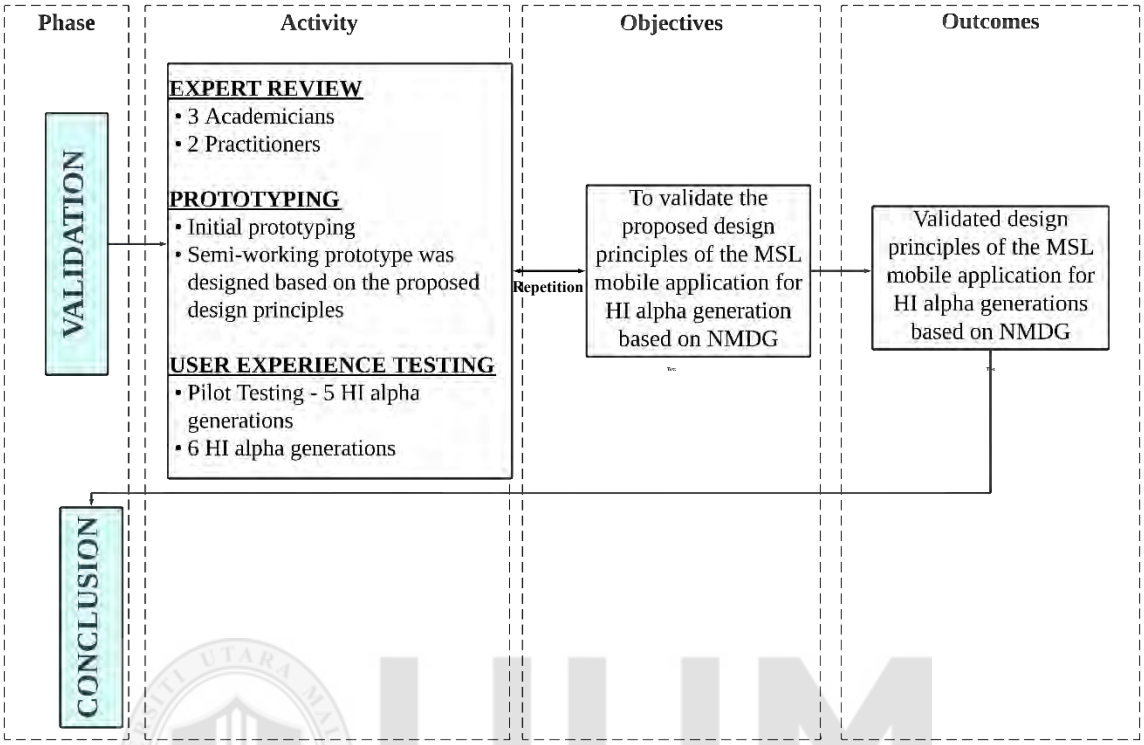


Figure 3.5. Phase 4: Validation

The validation phase is an essential part of ensuring the proposed design principles identified in the previous phases are helpful and reliable for future researchers to use as a manual in designing the MSL mobile applications for the HI learners, particularly the alpha generation. Three validation methods were chosen at this stage; expert review, prototyping, and user experience testing, as illustrated in Figure 3.5. Detailed explanations were described in Chapter 5. The following list discusses the sampling and instrument involved and each validation approach:

3.6.4.1 Sampling

The subjects of this study were selected using the purposive sampling approach as it focuses on specific population characteristics meaning the subjects are homogenous (Tashakkori, 2009). Chapter 2 highlighted the characteristics of the subjects who are the children born after 2010 and having limitations in utilizing their hearing organ, also known as Hearing Impaired Alpha Generations. In this study, six subjects were chosen to be involved. Three subjects are learners with partial hearing loss, and the remaining have total hearing loss.

Although the quantity is limited, the sample size has provided sufficient data to respond to the research questions. According to Butler (2021), qualitative study tends to be driven by the concepts of data rather than the number of subjects involved; thus, having a small number of subjects is sufficient as a sample size recommended to have five to seven subjects.

3.6.4.2 Validation through Expert Review Method

In general, expert review is one of the well-known methods widely used to evaluate the usability issues in developing systems or applications (Korhonen, 2009). This method involved the evaluators or inspectors based on their expertise and knowledge of the research fields to verify and validate the usability issues regarding the structure, navigation, functionalities, efficiency, and effectiveness of products (Azman, 2018). Previous

researchers highlighted a few criteria in choosing the experts or practitioners to be involved, further discussed in Chapter 5.

This study involved three experts and two practitioners with different backgrounds. Both experts have more than five years of experience related to research study. Besides, Ishaq (2021) highlighted that three to five numbers of experts are sufficient to recognize the usability issues in an application evaluation. The profile of the experts was discussed in Chapter 5. Then, a checklist of the proposed design principles for MSL mobile applications for HI alpha generation based on NMDG was designed as the instruments for the experts to review.

Next, the review process was carried out virtually due to COVID-19, which minimizes the physical interactions between individuals. At the end of this phase, the experts successfully validated the proposed design principles. The findings were gathered to be applied in designing the prototype for the second validation method that was extensively discussed in the following sections.

3.6.4.3 Validation through Prototyping Method

Validation is a method to confirm that the product, service, or system developed meets its specification and fulfils the intended purpose. It is also known as a quality control process used to evaluate the product with the support of the instruments such as prototypes (Ahmad et al., 2015). Several studies have proved that this method successfully validated the

products, which are studies made by Arbeiter (2016) and Borky (2019). The prototypes can be designed in two different types of prototypes which are low-fidelity and high-fidelity prototypes.

In this study, three versions of prototypes were developed to serve different functionalities. Firstly, an initial low-fidelity prototype was designed to visualize the users' representatives' ideas and outline the proposed design principles, as discussed in Chapter 4. Then, a semi-working prototype was designed to validate the proposed design principles. However, numerous issues arose during the pilot test, as discussed in Chapter 7. Thus, the prototype was re-designed according to the feedback and suggestions given during the pilot test to enhance the prototype and solve the issues. The semi-working prototype was designed in the Marvel Apps free online software. The rationale for choosing this software is because it is easy to explore and learn. Besides, it provides various templates design. Hence, it can save time in designing the prototype. It also supports different sizes of devices.

At the end of this phase, a prototype was successfully designed and developed based on the proposed design principles, indicating that the proposed design principles are valid and valuable for the developers. Next, the proposed design principles were validated through user experience testing that involves the actual users in testing the prototypes. Further details are described in the following sections.

3.6.4.4 Validation through User Experience Testing Method

User experience testing is the last validation method adopted in this study to validate the proposed design principles for the MSL mobile applications for HI alpha generations based on NMDG. The primary purpose of this user experience testing is to evaluate the usefulness of the proposed design principles rather than the effectiveness of the prototype, as the proposed design principles were designed to satisfy the needs of the HI alpha generations as the primary users. However, a pilot study was conducted before the actual evaluation.

A pilot test was crucial for qualitative research to ensure that the observation sessions conducted in the actual experimental evaluation were well prepared. This explains that the pilot test would assist this study in checking for errors, limitations, or other drawbacks in the evaluation preparations. This allows this study to make any necessary modifications or refinements before running actual evaluations. The pilot test should involve subjects with similar interests to those participating in the evaluation. This study conducted a pilot test with five HI alpha generations of Sekolah Pendidikan Khas Sungai Petani to ensure that. After ensuring that the prepared observation had no error, the evaluation was conducted with six HI alpha generations from the same school but in different classes. The rationale for conducting the pilot and actual testing in the same school is because of the homogenous characteristics.

The actual was conducted with the selected HI alpha generations using the semi-working prototype that had been designed previously. Based on the rationale of using the qualitative approach discussed in the previous sections, this study decides to apply the observation and picture rating to gather data during user experience testing. The subjects' behavior was observed through two cycles of observations which are individual and group.

The testing was carried out in the equipped music class, and two tablets associated with the prototype were prepared. Then, six subjects were involved, three males and three female students in the seven to nine age range. The subjects have been assigned to sit next to each other with the front row of female students and the back row with male students. So, they feel comfortable interacting with the prototype on their own. This is important because their behavior is the primary data for this testing process. In direct observation I (group tasks), the subjects' behavior was observed by how they interacted while experiencing the prototype. Then, in direct observation II (individual), their behaviors were observed to identify whether they could independently use the prototype and memorize the learning contents they had seen previously. This is to ensure that the proposed design principles that have been visualized in the prototype can evoke the subjects' cognitive ability.

At the end of this phase, the proposed design principles were successfully validated, and the subjects could complete the tasks given and memorize the learning contents. Hence, this shows that the design principles can evoke cognitive ability among the HI alpha

generations. In the following section, all the processes involved were revisited in the last phase, the conclusion phase.

3.6.5 Phase 5: Conclusion

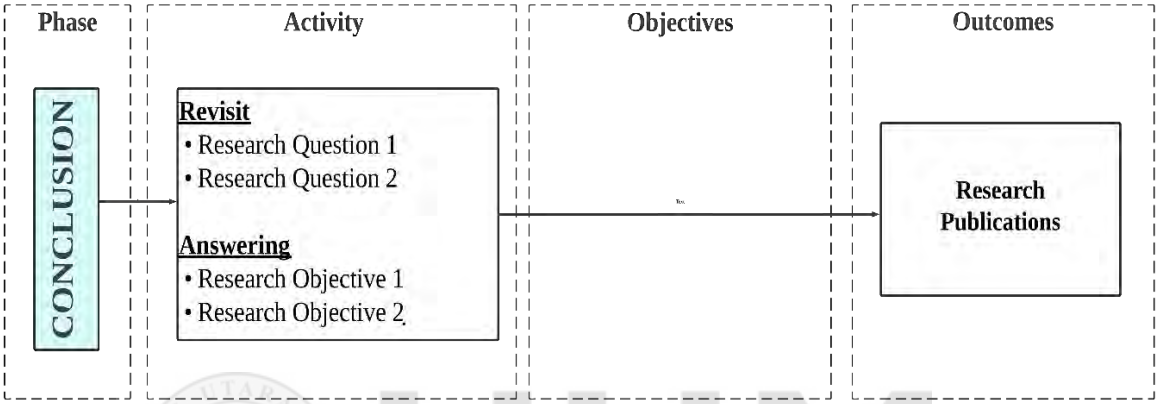


Figure 3.6. Phase 5: Conclusion

In this last phase, the findings were gathered in the previous phases and concluded by revisiting and answering all the research questions and objectives. Finally, this study was completed with the entire thesis and several publications as the main contribution to the body of knowledge and theory. Figure 3.6 illustrates the summary of the last sub-phases.

3.7 Chapter Summary

In conclusion, this chapter discusses the research methods adopted throughout this study. With the rationale of every approach discussed, Iterative triangulation methodology (ITM) has been adopted in this study, which involves three phases: theoretical, development, and evaluation. All the phases need to be iterated and adopted systematically to achieve the

objectives of this study. Then, five sub-phases from the design science research method were applied, which are (i) problem awareness, (ii) suggestion, (iii) construction, (iv) validation, and (v) conclusion. Each phase was described in detail with the activities carried out throughout this study. Details of the identification of the proposed design principles for the MSL mobile application for the HI alpha generations based on NMDG are discussed in the next chapter.

CHAPTER FOUR
CONSTRUCTION OF THE DESIGN PRINCIPLES FOR THE MSL MOBILE APPLICATION THROUGH UCD APPROACH

4.1 Overview

This chapter thoroughly demonstrates how the Malay Sign Language (MSL) mobile application's design principles were constructed utilizing Nielsen and Molich's Design Guidelines (NMDG). The user-centered design (UCD) approach was adopted to construct the design principles. Throughout the phase, experts and representatives of the actual users were involved. In this chapter, all relevant activities were covered in detail.

The main goal of constructing a new set of design principles for the MSL mobile application is to expand the context of the NMDG that Kumar (2019) has already formed, which considers the context of the mobile application for all users but is not particularly for hearing-impaired (HI) people, particularly the alpha generations. It is crucial to emphasize that this new set of design principles was created based on the extended NMDG by Kumar (2019) but is more focused on the context of the HI alpha generations. On top of that, three expert consultation sessions were carried out, as discussed in the following section.

4.2 Expert Consultations

The purposes of conducting expert consultation sessions are (i) to obtain better insight into the NMDG and (ii) to get opinions and suggestions from experts on the concepts of the MSL mobile application based on the NMDG. The background of the selected experts who participate in the consultation sessions is highlighted in the following subsection.

4.2.1 Background of Experts

There are three experts with different backgrounds have been selected to participate in the consultation sessions. One of the experts is an industry specialist, while the remaining are academicians. The qualifications of the experts are thoroughly outlined in Table 4.1. The following subsection went into additional detail about the methods used for this consultation.

Table 4.1

Experts' Background

Expert	Gender	Position	Background
A	Female	Senior Lecturer	• Expert in children interaction and multimedia design for disabled people field. • More than ten years of teaching experience in multimedia and human-computer interaction field

Table 4.1 (Continued)

B	Male	Associate Professor	• Experience in conducting research related to the hearing-impaired individuals • More than fifteen years of teaching experience in multimedia and application design for disabled people.
C	Male	Head of Malaysian Federation of Deaf (MFD) Terengganu	• Hearing-impaired teacher • More than ten years of experience providing free sign language classes for hearing-impaired individuals.

4.2.2 Instruments and Methods

As a kickstart of the consultation sessions, email invitations were sent to the experts through their official email addresses to invite them to participate in the consultation sessions. Along with the email, the research details were explained with the attachment of the research operational template (ROT) in Appendix A. After the experts agreed with the invitations, a list of the NMDG by Kumar (2019) with detailed explanations and the details of the sessions were sent to their email as attached in Appendix B.

Next, three consultation sessions were carried out separately with the experts. As for the academicians, the consultation sessions were carried out virtually through the Google Meet platform as requested by the academicians. The virtual sessions with the academicians were conducted for one hour accordingly. In contrast, the consultation session with the industry expert was conducted physically at Pusat Pendidikan Khas, Kuala Terengganu, Malaysia. The industry expert is a HI individual. To ensure that he could provide the input in great

depth, he thus requests a physical consultation. Figure 4.1 depicts the industry expert involved and the research team.

Figure 4.1. Industry expert and research team.

Then, due to hearing loss, the industry expert has communication and hearing impairments. As depicted in Figure 4.2, he suggested using writing as a form of communication during the consultation rather than paying a translator to translate the sign language. This preserves the integrity and reliability of the data gathered. The following subsection provides a detailed explanation of the consultation session findings.

Figure 4.2. The industry experts write the answers for feedback

4.2.3 Results and Findings of the Expert Consultations

Previously, three consultation sessions have been carried out with the industry experts and academicians. To conclude the input and suggestions from the sessions, all experts show positive feedback on the ideas of constructing the design principles of the MSL mobile application for the HI alpha generations. Besides, both academicians agreed that the design principles of the MSL mobile application could be constructed based on the NMDG extended by Kumar (2019). They also decided that the existing NMDG should be extended by considering the context of HI individuals to help future researchers design and develop mobile applications that could satisfy the users' needs. Table 4.2 tabulated the results of the consultation sessions with the academicians that have been analyzed using the thematic analysis method.

Table 4.2

Thematic Analysis of the Consultations with Academicians

No	Quotations	Heuristics NMDG by Kumar (2019)
1	/…Based on my suggestions, the design principles should mention that the contents, information, or theories related to the learning material should be up-to-date and adhere to the latest local education standard. The design principles should also mention that the concern is the learning contents. For example, 'The sign language learning content should adhere to the local education standard and up to date.' Match between the system and the real world means the applications should follow the current and latest trend of the real world…. /	Match between system and the real world
2	/…I believe the application should be consistent from the beginning until the end. This is to prevent the users from being lost in the middle of experiencing the applications. I suggest that the design principles should mention that all elements in the apps should be consistent, including the navigation, button, colors, font sizes, and types…. /	Consistency and Standards
3	/…Providing aesthetic and minimalist design might not be for the kids because they need the interface that could catch their attention, such as bright colors, cartoons, and color blocking. The HI children rely significantly on their visuals, so they need a more attractive interface. The design principles could mention that 'The application interface should be attractive with bright colors and usage of cartoons characters'…. /	Aesthetic and minimalist design
4	/…This is where the applications allow the users to recognize the functions instead of memorizing them. The application should provide something that could trigger their memory to recognize. For example, use the button exit in red with 'X' instead of using text like 'EXIT' because they know X is for exit already if the application consistently uses it for every screen …. /	Recognition rather than recall
5	/…I agree that the HI people rely on visuals and graphics a lot. It would be good if the application could fully utilize multimedia elements instead of plain texts and images. Put a lot of videos and animations to catch their attention. …. /	Visual representation

Table 4.2 (Continued)

6	/…The applications should tell the users why they provide the error to their actions. For example, if they have mistakenly clicked on the button they shouldn't click, the application should tell them through a pop-out or alert. However, in the context of children learners, the application should prevent them from making mistakes to prevent them from being distracted…. /	Help users recognize, diagnose, and recover from errors.
7	/…The means of control and freedom is the users were given the right to choose. For example, they can leave the application at any time, such as in the middle of learning they feel pressured, then they can leave that learning and continue to other tasks …. /	User control and freedom
8	/…The applications should provide the pop-out dialogue or anything that could attract their attention when they make a mistake. The applications also need to provide ways for them to recover from errors. For example, the user mistakenly clicks on the exit, so the pop-out dialogue should give the alert, 'Do you want to leave? Click yes if true, no to cancel' …. /	Error prevention
9	/…This is quite like the freedom of the user, but this allows the users to have flexibility. For example, the users can jump to the next question without answering them or fast forward the video learning…. /	Flexibility and efficiency of use
10	/…This is where the application could control the users from making massive mistakes where it allows the users for certain functions only. For example, an application only provides click-and-play functions, not typing…. /	Selection driven commands
11	/…As for the visibility of system status, the applications should tell the users their current states. For example, the application put the progress bar to let the users know their progress for the tasks they were doing …. /	Visibility of system status
12	/… I think this is not important because the application should be learnable because the children will not read the manuals because they will go straight to the applications and experience them…. /	Help and documentation
13	/… Fitting everything on one screen is unnecessary because they must interact with the application. By providing the continuity of the screen, it could attract their attention…. /	Content organization

Apart from that, the industry expert agreed with the academicians that the learning content should be prioritized for mobile learning applications. The learning content should follow the most recent local education standard. Furthermore, he suggested that the learning content should be designed based on the latest books the Ministry of Education provided, as shown in Figure 4.3. He also emphasizes that HI students tend to be drawn to visuals like videos and animation because they rely heavily on them. The industry expert noted that not all HI individuals had complete hearing loss. Some of them may still be able to hear, although with limited hearing capacity. Thus, adding sound to the applications would be another developer option. Then, he agreed that colors are crucial for alpha generations because they tend to be drawn to the colorful interface.

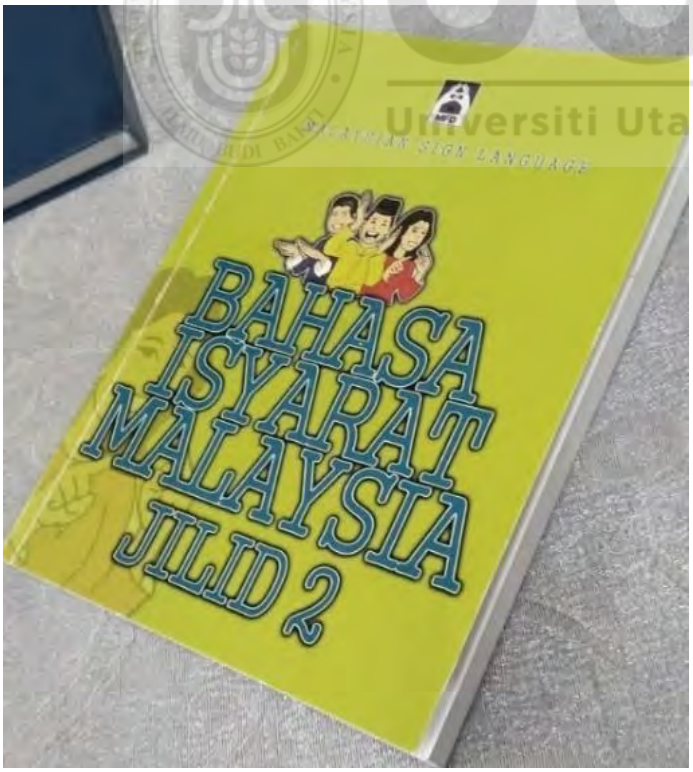


Figure 4.3. Sample of the book for sign language learning

In conclusion, there are five design principles for the MSL mobile applications were initially proposed based on the results of the consultations with the experts that can be described as follows:

i. People learn better from animations 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 elements on the screen.

iii. Using colors is essential for children as it could attract their attention during learning.

iv. Use the animations that the children are familiar with.

v. Use more simple words to enhance children's cognitive ability.

Then, the initially proposed design principles were discussed extensively with the users' representatives for feedback and comments. It is known as the user-centered design (UCD) approach. Further explanations were discussed in the following section.

4.3 User-Centered Design (UCD) Approach

The involvement of the actual users throughout the design and development of the system or product to reduce the usability issues and ensure the products meet the users' needs are known as the User-Centered Design (UCD) Approach.'. In this study, the users' representatives were chosen to represent the actual users to construct and confirm the design principles of the MSL mobile applications. This ensures that the design principles

can meet the actual users' expectations and needs. The rationale for involving the users' representatives instead of the actual users is because of the limitations of the actual users of this study, who are the HI alpha generations. They are children with hearing impairment that have difficulties utilizing sign language for communication. Thus, they need fewer complex methods in approaching them for feedback. The details of the process involved throughout the UCD activities were described as follows:

4.3.1 Participants

According to Sargeant (2012), the number of participants for qualitative studies are not as important to the selection and background of the participants. They must be purposeful to be selected as participants and they must be the participants that able to enhance the understanding of the phenomenon of the study. In this study, are two teachers of the HI alpha generations chosen to represent the actual users. The rationale for selecting the teachers of HI alpha generations as the users' representatives is that they have more than ten (10) years of experience teaching the HI alpha generations. Besides, they have experience in designing digital learning content for their students. Thus, they know the needs of their students better.

Table 4.3 depicts the criteria, justifications of the subjects involved in constructing the design principles, and tasks. The instruments and methods applied are explained in the following subsection.

Table 4.3

Users, Criteria, Justifications for Selecting the Subjects, and Tasks.

Users	Criteria	Justifications	Tasks
2 Teachers	They have been teaching the HI alpha generations for more than ten years.	The teaching experience could increase their confidence in this study and provide the requirements for designing the MSL mobile application by participating as the user representatives.	List the MSL mobile application's needs, requirements, contents, and design principles based on NMDG.

4.3.2 Instruments and Methods

The potential teachers of the HI alpha generations were contacted through their official email addresses and invited to participate in this study as users' representatives. The email invitations were issued along with the research operational templated (ROT), attached in Appendix A, to provide the teachers access to the research's concepts and ideas. Following their approval, the teachers were given a list of the NMDG by Kumar (2019) that had been mapped with the initially proposed design principles by the experts and was given to the teachers to review. They have a week to go over the checklist.

The proposed design principles for the MSL mobile application were then discussed with the teachers in a one-hour virtual group discussion using Google Meet, as shown in Figure 4.4. An early low-fidelity prototype was developed to depict the teachers' design principles. Chapter 6 covered the procedure for developing the low-fidelity prototype in more detail. The process was repeated until the teachers were satisfied and agreed with the design principles. Weekly meetings were held virtually to discuss the proposed design principles.

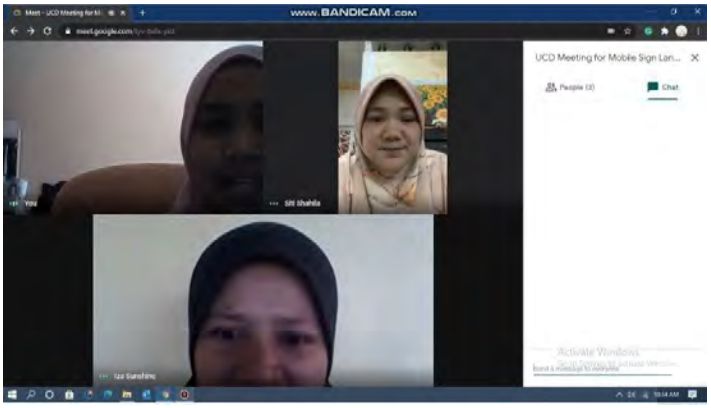


Figure 4.4. Virtual meetings with users' representatives

4.3.3 Results and Findings

Previously, several virtual group discussions have been carried out with the teachers of the HI alpha generations as the users' representatives. The results of the discussions were then analyzed using the thematic analysis method. Table 4.4 tabulated the results of the discussions.

Table 4.4

Thematic Analysis of the Virtual Discussions with the Teachers

No	Quotations	Heuristics NMDG by Kumar (2019)	Design Principles
1	/…Currently, the sign language mobile applications that have been developed do not designed based on the current learning contents and do not follow the standard of Malaysian education, which is the KTBM versions, as they mostly use the BIM learning contents…. /	Match between system and the real world	Matching the sign language learning content with the local education standard

Table 4.4 (Continued)

2	/…The learning application should provide exercises to assess the learners' understanding and ensure they can memorize the learning content. Besides, the exercises provided must be the same as the learning content shown …/	Consistency and Standards	The sign language video learning content must be coherent with the exercises provided.
3	/… Yes, I agree with this initially proposed design principle as the screen should not be too crowded, and it is enough to have only 5-7 elements per screen to enhance the learners' memorability and understandability of the learning contents …/	Aesthetic and minimalist design	Minimize the HI learners' cognitive load by minimizing the interface design.
4	/… I think you need to change the color of the interface as the color should be minimal but attractive with a good color combination such as cream for the background…/	Aesthetic and minimalist design	The interface's color should be minimal but attractive with a good color combination.
5	/… Please ensure the characters are recognizable to avoid misunderstanding and use the characters that are attractive to attract the learner's interest…/	Recognition rather than recall	It is advisable to use the cartoon character the HI alpha generation is recognizable because they easily remember what they are familiar with.
6	/… Apart from that, the font should be consistent in size and style. It is good if the designer can follow the stand font such as Calibri or Azim. …/	Consistency and standards	As for sign language learning, content should follow the standard font, such as Calibri. Besides, the size of the font should be consistent for all screens.

Table 4.4 (Continued)

7	/… I suggest you should use more combination of multimedia elements rather than texts and static images as they rely more on their visuals rather than texts to catch their attention…/	Visual representation	Use more multimedia elements than text and static images as the HI learners rely more on graphics than texts.
8	/… The sizes of the graphics, such as the cartoons or sign language images, should be consistent, and the quality also needs to be enhanced…/	Consistency and standards	The sizes and quality of images or graphics should be maximized and consistent.
9	/… I think the button should be designed to look more clickable and consistent in the colors according to the functionalities, such as the exit should be red, should be green, and more…/	Recognition rather than recall	The button design should be clickable and consistent according to the functionalities.
10	/… It is good to allow the users to undo their actions and redo them. This is because the users are disabled children; thus, they tend to make mistakes when exploring the application …/	Help users recognize, diagnose, and recover from errors.	The application should be associated with undo and redo button for the HI learners to recover from mistakes.
11	/… Besides from the undo and redo, they need to have the choice to continue the learning or quit the teaching as they are easily distracted and boring …/	User control and freedom	The applications should enable the HI learners to exit the application.
12	/… To catch their attention, it is good to have a pop-out message or blinking message to convey the critical message to them…/	Error prevention	The sign language application feedback should be designed with pop-out dialogue to catch HI learners' attention.
13	/… As for the questions sections, they need to have the flexibility of choosing the questions they want to answer, or they can skip any questions they want…/	Flexibility and efficiency of use	Ensure flexibility of navigation for the HI learners in using the application

Table 4.4 (Continued)

14	/… For me, I suggest you should use more buttons or click-and-play functions and avoid designing the activities that need them to write or type to prevent them from making massive mistakes and leading to distractions and frustrations …/	Selection driven commands	Maximized the usage of a button as well as click-and-play functions
15	/… I see from the prototype the design is lacking in providing the instructions for every screen. The instructions are essential to ensure the learners are not lost in the applications …/	Visibility of system status	Ensure all the screens provide instructions to notify the HI learners of their current states.
16	/… I do not see that they need the manuals, but it is good if you can provide the manuals in videos so that they can refer anytime they want, but the applications themselves should be learnable for them. Using the chat box to assist them is not a good option …/	Help and documentation	Assist the HI learners in using the application by providing a manual with a video tutorial

Sixteen design principles of the MSL mobile application were constructed based on NMDG by Kumar (2019), as shown in Table 4.4. It is suggested by Kumar (2019) to optimize the learning contents to fit on one screen, and multiple screens can be used to display the contents. However, according to the users' representatives, this does not apply to the context of HI individuals, especially the alpha generations. This is because they need a simple interface that is less crowded to ensure they can memorize and understand the learning contents. Thus, the users' representatives are not suggested to provide different learning content within one screen to minimize the cognitive loads for the learners. Accordingly, Table 4.5 highlights the design principles successfully proposed and confirmed by the users' representatives.

Table 4.5

Identified 16 Design Principles for the MSL Mobile Application for HI Alpha Generation Based on NMDG

No	Proposed Design Principles for Malay Sign Language Mobile Application for Hearing-Impaired Alpha Generation	Description
Usability Heuristics for Mobile Application (1): Visibility of the system status		
1	Ensure all the screens provide instructions to notify the user's earners of their current states.	All the screens should be provided with instructions so that the users know their current states.
Usability Heuristics for Mobile Application (2): Match between system and real world		
2	Matching the sign language learning content with the local education standard	The sign language learning content should be similar to the local education standard to ensure it is standardized and avoid misunderstanding.
Usability Heuristics for Mobile Application (3): User Control and Freedom		
3	The applications should enable the HI learners to leave the application anytime.	The users should be allowed to leave the applications with a single click.
Usability Heuristics for Mobile Application (4): Consistency and Standard		
4	The sign language video learning content must be coherent with the exercises provided	The exercises must be consistent with the video learning to measure the cognitive ability of the mobile applications.
5	Use standard fonts and sizes for the texts.	As for sign language learning, content should follow the standard font, such as Calibri. Besides, the size of the font should be consistent for all screens.
6	The sizes and quality of images or graphics should be maximized and consistent.	The quality of images, graphics, and videos should be maximized to attract the users' attention as they are attracted more to the visuals.
Usability Heuristics for Mobile Application (5): Error Prevention		
7	The sign language application feedback should be designed with pop-out dialogue to catch users' attention.	Every action made by the users should be associated with the feedback through pop-out dialogue to avoid being lost in the application. For example, an alert should be provided every time they answer the questions to notify them whether their answers are right or wrong.

Table 4.5 (Continued)

Usability Heuristics for Mobile Application (6): Recognition Rather than Recall		
8	The button design should be clickable and consistent according to the functionalities.	The buttons or menus should be consistent, and the colors should follow the standards.
9	Use the recognizable characters in the application design	It is advisable to use the cartoon character recognizable by the users because they easily remember what they are familiar with.
Usability Heuristics for Mobile Application (7): Flexibility and Efficiency of Use		
10	Ensure flexibility of navigation for the users in using the application	The users should have flexibility while utilizing an application to avoid feeling distracted and pressured. For example, HI learners can skip the questions that they do not want to answer to the following questions.
Usability Heuristics for Mobile Application (8): Aesthetic and Minimalist Design		
11	Minimize the cognitive load by minimizing the interface design.	The interface design should be simple and less crowded. According to usability experts, having only 5-7 elements within a screen is good for enhancing cognitive ability.
12	The interface's color should be minimal but attractive with a good color combination.	Using attractive colors but less crowded to attract their attention and interest is advisable.
Usability Heuristics for Mobile Application (9): Help Users Recognize and Recover from Errors		
13	The application should be associated with undo and redo button for the HI learners to recover from mistakes.	A sign language application should provide 'Redo' and 'Undo' buttons to help users have a smooth experience using the applications. The users tend to make massive mistakes while using the applications.
Usability Heuristics for Mobile Application (10): Help and Documentation		
14	Assist the users in using the application by providing a manual with a video tutorial	The users rely on video and assistance from their parents to help them learn. Hence, a video tutorial is needed to explain how the applications work to the parents and HI learners.
Usability Heuristics for Mobile Application (11): Selection Driven Commands		
15	Maximized the usage of a button as well as click-and-play functions	Optimizing the usage of buttons and providing click-play functions is advisable to avoid making massive mistakes when interacting with the applications. The use buttons should be fully utilized.
Usability Heuristics for Mobile Application (12): Visual Representation		
16	Use more multimedia elements than text and static images as the HI learners rely more on graphics than texts.	Images and pictures can enhance memorability as they rely heavily on visuals rather than plain texts.

Identifying the design principles of the MSL mobile application for HI alpha generations through the UCD approach was one of the goals of this study, and it has now been fulfilled. For future researchers to use as a guide while designing the MSL mobile application for HI learners, especially the alpha generations, the proposed design principles were then validated to guarantee their validity and dependability. Expert review, prototyping, and user experience testing were the three validation methods used. In the following chapters, additional details of the validation procedure were covered.

4.4 Chapter Summary

In conclusion, sixteen design principles of the MSL mobile application have been successfully constructed with the involvement of the experts and teachers of the HI alpha generations as the actual users' representatives. The design principles were constructed based on the NMDG by Kumar (2019). Three experts were involved during the experts' consultations, and the design principles were initially proposed. Then, the users' representatives were involved in reviewing and constructing the design principles through several online discussions and the development of the initial low-fidelity prototype. At the end of this phase, sixteen design principles of the MSL mobile application were successfully constructed. Then, to ensure the validity and reliability of the proposed design principles, they were validated through three validation approaches: expert review, prototyping, and user experience testing, to assess their reliability. The details of the validation process were extensively discussed in the following chapters.

CHAPTER FIVE
EXPERT REVIEW

5.1 Overview

The previous chapter has explained the tasks involved in constructing the Malay Sign Language (MSL) mobile application's design principles based on Nielsen's and Molich's Design Guidelines (NMDG). Sixteen design principles have been successfully constructed. The validity and reliability of the design principles were then confirmed using three different methodologies. Expert review is one of the validation methods, and it was covered in detail in this chapter.

5.2 Expert Review

The expert review method is one of the well-known evaluation and validation methods researchers widely use to inspect usability issues in specific product design and development (Korhonen, 2009). It involves the experts as evaluators or inspectors based on their expertise, knowledge, and experience in the fields related to the study. According to Azman (2018), experts are responsible for reviewing, verifying, and validating usability concerns connected to specific products' structure, navigation, functionality, efficiency, and effectiveness.

On the other hand, Ishaq (2021) suggested that three to five experts are sufficient to detect usability issues with the application and validate the evaluation's findings. Experts can

come from various backgrounds, such as practitioners and scholars. Then, as shown in Table 5.1, Azman (2018) suggests criteria for choosing academics and practitioners to participate in the research.

Table 5.1

Criteria of Academicians and Practitioners

Types of Experts	Criteria
Academicians	a. A PhD holder in the fields related to research study. b. Have been studying or practicing related to the research study.
Practitioners	a. Have at least five years of experience in the industry related to research studies.

Source: Azman (2018)

Accordingly, to validate the proposed design principles of the MSL mobile application, five experts from diverse backgrounds and fields were chosen to participate in this study. The selected experts' demographic details are further described in the following section.

5.3 Experts' Demographic

The potential experts were identified through peers' recommendations, portals, websites, and personal social media such as LinkedIn and ResearchGate. As Azman (2018)

suggested, Table 5.2 lists the gender, position, academic background, field of expertise, years of experience, and affiliation of the chosen experts.

Table 5.2

Experts' Demographics

Expert	Gender	Position	Academic Background	Field of Expertise	Years of Experience	Affiliation
A	Female	Senior Lecturer	Doctor of Philosophy Human-Computer Interaction	Human-Computer Interaction (HCI)	14	Universiti Teknologi MARA (UiTM)
B	Male	Associate Professor	Doctor of Philosophy Information Systems Technology	Multimedia	15	Universiti Utara Malaysia (UUM)
C	Female	Senior Lecturer	Doctor of Philosophy (Information Technology)	Children Interaction Design	28	UiTM
D	Female	Teacher	Bachelor of Education	Early Education for Children	25	Sekolah Pendidikan Khas Sungai Petani, SKPK
E	Female	Teacher	Bachelor of Primary School Education (Hons.) Hearing Impaired Disabilities Learning	Early Education for Children	10	SKPK

As tabulated in Table 5.2, five experts with different academic backgrounds and positions were chosen to be involved in this study. This is important for this study to have established reviews and comments. There are two categories of experts involved, which are academicians and practitioners. As for the position, two experts are the senior lecturer, one the associate professor, and the remaining teachers of the HI alpha generations. The academicians are lecturers from different institutions with teaching experience of more than ten years in Human-Computer Interaction (HCI), children interaction design, and multimedia design. They graduated with a Doctor of Philosophy (Ph.D.) in different majors related to this study.

The primary purpose of involving academicians with diverse backgrounds is to gain better insight into the theories related to the studies from different viewpoints. At the same time, two practitioners who are the teachers of the HI alpha generations with more than ten years of teaching the HI alpha generations in government, particularly in early childhood education, were chosen as experts. Their academic qualifications are a bachelor's degree in child education for Disabilities. Thus, all the experts have met the criteria Azman (2018) suggested. The methods and procedures involved were further described in the following section.

5.4 Methods and Procedures

Throughout the review process, email was used as a medium of communication. First, an official email was sent to the official email address of the identified potential experts. The

email highlighted the research details, such as research background, significance, research scopes, and the invitation for the experts to be part of the research study. The sample of the email invitation was attached in Appendix C. Having agreed to be appointed as an expert reviewer, a dean's official appointment letter as an expert was sent to them, as attached in Appendix D. Then, a checklist that consists of the proposed design principles and the NMDG, as attached in Appendix E, was also attached via email. The experts were given one to two weeks to complete the review process.

As previously stated, the checklist of the proposed design principles of the MSL mobile application serves as the main instrument for the expert review method. The checklist's format was modified from Afua (2020). The experts were first required to complete a demographic profile, which included questions on their gender, position, educational background, area of expertise, years of experience, and affiliation. Following that, the checklists were associated with the Likert Scale with modifications from (Negative, Neutral, Positive) to (D-Disagree and A-Agree). The experts were asked to validate the items by selecting "agree" (A) if they agree with the suggested design principles and "disagree" (D) otherwise. Finally, they were required to provide comments and feedback in the feedback (F) column based on their knowledge, experience, and perceptions. The following sections discuss the findings of the review.

5.5 Results and Findings

The gathered data were tabulated in Table 5.3 based on the review process. It can be concluded that most experts agreed with the proposed design principles for the MSL mobile application for the HI alpha generations that have been identified based on the NMDG that has been extended by Kumar (2019). However, some modifications (highlighted in yellow) were suggested by the experts to enhance the reliability of the proposed design principles.

Table 5.3

Results of the Expert Review

No	Design Principles	Heuristics Usability: NMDG	Description	Experts				
				A	B	C	D	E
1	Ensure all the screens provide instructions to notify the user's earners of their current states.	Visibility of the system status	All the screens should be provided with instructions so that the users know their current states.	Agree	Agree	Agree	Agree	Agree
2	Matching the sign language learning content with the local education standard	Match between system and real world	The sign language learning content should be similar to the local education standard to ensure it is standardized and avoid misunderstanding.	Agree	Agree	Agree	Agree	Agree
3	The applications should enable the HI learners to leave the application anytime.	User Control and Freedom	The users should be allowed to leave the applications with a single click.	Agree	Agree	Agree	Agree	Agree

Table 5.3 (Continued)

4	The sign language video learning content must be coherent with the exercises provided	Consistency and Standard	The exercises must be consistent with the video learning to measure the cognitive ability of the mobile applications.	Agree	Agree	Agree	Agree	Agree
5	Use standard fonts and sizes for the texts.		As for sign language learning, content should follow the standard font, such as Calibri. Besides, the size of the font should be consistent for all screens.	Agree	Agree	Agree	Use Comic Sans or Century Gothics Font.	Agree
6	The sizes and quality of images or graphics should be maximized and consistent.		The quality of images, graphics, and videos should be maximized to attract the users' attention as they are attracted more to the visuals.	Agree	Agree	Agree	Agree	Agree
7	The sign language application feedback should be designed with pop-out dialogue to catch users' attention.	Error Prevention	Every action made by the users should be associated with feedback through pop-out dialogue to avoid being lost in the application. For example, an alert should be provided every time they answer the questions to notify them whether their answers are right or wrong.	Agree	Agree	Agree	Agree	Agree

Table 5.3 (Continued)

8	The button design should be clickable and consistent according to the functionalities.	Recognition Rather than Recall	The buttons or menus should be consistent, and the colors should follow the standards.	Agree	Agree	Agree	Agree	Agree
9	Use recognizable characters in the application design.		It is advisable to use the cartoon character recognizable by the users because they easily remember what they are familiar with.	Agree	Agree	Agree	Agree	Agree
10	Ensure flexibility of navigation for the users in using the application	Flexibility and Efficiency of Use	The users should have flexibility while utilizing an application to avoid feeling distracted and pressured. For example, HI learners can skip the questions that they do not want to answer to the following questions.	Agree	Agree	Agree	Agree	Agree
11	Minimize the cognitive load by minimizing the interface design.	Aesthetic and Minimalist Design	The interface design should be simple and less crowded. According to usability experts, having only 5-7 elements within a screen is good for enhancing cognitive ability.	Agree	Agree	Agree	Agree	Agree
12	The interface's color should be minimal but attractive with a good color combination.		Using attractive colors but less crowded to attract their attention and interest is advisable.	Agree	Agree	Agree	Agree	Agree

Table 5.3 (Continued)

13	The application should be associated with undo and redo button for the HI learners to recover from mistakes.	Help Users Recognize and Recover from Errors	A sign language application should provide 'Redo' and 'Undo' buttons to help users have a smooth experience using the applications. The users tend to make massive mistakes while using the applications.	Agree	Agree	Agree	Agree	Agree
14	Assist the users in using the application by providing a manual with a video tutorial	Help and Documentation	The users rely on video and assistance from their parents to help them learn. Hence, a video tutorial is needed to explain how the applications work to the parents and HI learners.	It could be an option, but the application needs to be learnable	Agree	Agree	Agree	Agree
15	Maximized the usage of a button as well as click-and-play functions	Selection Driven Commands	Optimizing the usage of buttons and providing click-play functions is advisable to avoid making massive mistakes when interacting with the applications. The use buttons should be fully utilized.	Agree	Agree	Agree	Agree	Agree
16	Use more multimedia elements than text and static images as the HI learners rely more on graphics than texts.	Visual Representation	Images and pictures can enhance memorability as they rely heavily on visuals rather than plain texts.	Agree	Agree	Agree	Agree	Agree

As exhibited in Table 5.3, most experts agreed with the proposed design principles of the MSL mobile applications. However, the experts made a few suggestions to enhance the proposed design principles. Expert A suggested that the application should be learnable by the users at first glance, and the video tutorial should only be an option for the users. In contrast, most experts agreed that the video tutorial should be included in the applications for the HI learners and their parents to get initial views on the applications before experiencing them.

Then, Expert D suggested using the Comic Sans or Century Gothic fonts in designing the application for the HI alpha generations, as it is the standard font used in school learning. In Addition, Expert D also suggested that the design principles should highlight how the application interface should be designed based on the color, button design, cartoon characters, and contents. It should be directly mentioned in the design principles, such as the button should be the red color for exit and the cartoon should be recognizable by the users. Besides, Expert C also suggested maximizing the usage of the multimedia elements to attract the users' attention as they rely a lot on their visuals rather than plain texts.

Moreover, further comments from all the experts were recorded in this study, as depicted in Table 5.4. Some comments were rephrased from the original versions to convey a more precise meaning.

Table 5.4

Additional Feedback and Comments from Experts

Expert	Feedbacks and Comments
Expert A	a. The design principles should be addressed in short, simple sentences but directly for the HI alpha generations context. b. The applications must be consistent by comprising the different levels of difficulties for better learning outcomes. The background color of the applications must blend well with the graphics and fonts. c. The background color of the applications must blend well with the graphics and fonts. d. The cartoon characters used should be utilized accordingly, referring to the age range of users. e. The use of multimedia elements must be planned and organized. f. The quality and size of images must depend on the screen size of the mobile devices. It requires further specification of the screen size. g. Necessary instructions are required associated with the redo and undo action h. It is good to have the flexibility of navigation in an application but needs to design better flow, so the learners do not neglect the vital learning content. i. It is good to offer other interaction options besides clicking the button and playing function j. The application should be learnable so that manual video will be an option for the users
Expert B	a. The use of multimedia elements in applications is needed mainly to explain the process.

Table 5.4 (Continued)

Expert C	a. Sign language design should be consistent. b. Suggest surveying color and cartoon characters or animations chosen with the children. c. Need to have the more visible font and preferred size. d. Provide blinking stars or good symbols for the correct answers and provide motivated logos or characters for the wrong answers. e. Make simple instructions. **f.** The tutorial video is suitable for explaining step-by-step through videos and images
Expert D	a. The content of the sign language learning should follow the formal sign language, the 'Kod Tangan Bahasa Malaysia (KTBM)' contents, to avoid misunderstanding for the HI alpha generation.
Expert E	a. It is advisable to use 'Comic Sans' or the 'Century Gothics' font for the text related to the learning contents to avoid confusion for the HI alpha generation.

Based on the comments, it is concluded that most experts focused on the learning content, interface design, multimedia components, and the interactivity of the applications since it is the crucial element of the design principles. Besides, most experts touch more on the design principles based on the NMDG. However, helpful feedback and suggestions were taken into significant consideration when designing the prototype of the MSL mobile applications.

5.6 Justifications of Results and Findings

As discussed earlier, sixteen proposed design principles of the MSL mobile applications for HI alpha generation based on NMDG were highlighted. The proposed design principles

were reviewed and validated by two categories of experts which are academicians and practitioners. Both categories of experts came from different backgrounds. However, most of the experts agreed on the proposed design principles but with few adjustments needed, as mentioned through the feedback and suggestions.

Expert A suggested removing the video tutorial or making it an option for the application since she believed that the applications should be learnable by the users. However, the practitioners claim that the video tutorial was required to introduce the application to the HI learners and to pique their enthusiasm for using it. In Addition, other experts also agreed that the HI learners needed this video tutorial function to provide them with a better understanding of the features offered by the applications and to assist them when necessary. As mentioned by the practitioners, the HI learners rely a lot on visuals; hence providing the video tutorial will be more helpful in helping students understand the applications.

Then, to avoid confusion among the students, experts Expert D and E suggested that the font styles used in the applications adhere to the requirements specified by the Ministry of Education, and the practitioners made it clear that the learning material should conform to the 'Kod Tangan Bahasa Malaysia (KTBM)' standard. To ensure that the HI alpha generations may have a seamless learning experience through the application, it is understandable that the learning materials and typefaces must adhere to the requirements that the practitioners have underlined.

On the other hand, the academician experts touch more on the usability and design of the interface. The feedback and comments can be concluded as follows:

i. The interface should be consistent regarding the size of images and fonts used, and the primary color must blend well with the graphics and texts.

ii. The chosen characters should be recognizable, and the quality of images must be consistent and depend on the screen size of the mobile devices.

iii. Maximize the usage of multimedia elements such as texts, graphics, audio, video, and animations to attract the users' attention.

iv. The instructions are necessary for every interface to avoid the user's loss in the application, and the education must be short, straightforward, and understandable.

v. The application should be flexible and have good navigability.

Having reviewed and analyzed all the comments and feedback provided by the experts, it can be concluded that the proposed design principles have been successfully validated through the expert review method as tabulated in Table 5.5.

Table 5.5

Sixteen Proposed Design Principles Validated by Experts through Expert Review Method

No	Proposed Design Principles for Malay Sign Language Mobile Application for Hearing-Impaired Alpha Generation	Description
	Usability Heuristics for Mobile Application (1): Visibility of the system status	
1	All screens should be provided with the instructions for the HI alpha generations to be aware of their current states.	All screens should have the instructions or titles of the screens for the HI alpha generations to be aware of their current states and avoid them from being lost in the applications.
	Usability Heuristics for Mobile Application (2): Match between system and real world	
2	The sign language learning contents provided should follow the local education standards for the HI alpha generations.	The contents of the sign language learning provided in the applications should follow the local education standards to prevent the HI alpha generations from being confused about the learning contents that are different from their learning at school.
	Usability Heuristics for Mobile Application (3): User Control and Freedom	
3	The MSL mobile applications should allow the HI alpha generations to leave the applications anytime.	The HI alpha generations quickly get bored and distracted in a particular situation. Thus, they need to be given the flexibility in controlling the applications, such as leaving the applications at any screen they want to stop exploring.

Table 5.5 (Continued)

Usability Heuristics for Mobile Application (4): Consistency and Standard		
4	The quizzes or exercises provided must be coherent with the contents of the video learning.	As additional features to assess the HI alpha generation's cognitive ability, quizzes or extra exercises could be provided. Still, the exercises should be similar to the video learning content to avoid misunderstanding.
5	The text fonts used in the MSL mobile applications should follow the local education standard font types and sizes.	As for sign language learning, content should follow the standard font, such as Comic Sans or Century Gothics font. Besides, the sizes of the fonts should be standardized and consistent for all screens.
6	The sizes and quality of the graphics, videos, and animations provided in the MSL mobile applications should be maximized and consistent.	The HI alpha generations tend to attract multimedia elements such as video, graphics, and animation rather than text. Using images and pictures can enhance their memorability. Thus, providing high-quality multimedia elements in the MSL mobile applications is advisable.
Usability Heuristics for Mobile Application (5): Error Prevention		
7	Timely feedback should be provided in the MSL mobile applications through the pop-out dialogue to catch the attention of the HI alpha generations.	Every action made by the users should be associated with feedback through pop-out dialogue to avoid being lost in the application. For example, an alert should be provided with minimal options to prevent them from making massive mistakes.

Table 5.5 (Continued)

Usability Heuristics for Mobile Application (6): Recognition Rather than Recall		
8	The button in the MSL mobile application should be clickable and consistent according to the functionalities.	Buttons or menus should be consistent, and the colors should follow the standards. Avoid using texts and images as buttons. The design of the button should be clickable and avoid blinking button design. The button should be associated with the labels. The colors of the button should be consistent and follow the standard that has been imposed.
9	The characters used in designing the MSL mobile applications should be recognizable and suitable to the contexts of the HI alpha generations.	It is advisable to use characters recognizable by the alpha generations, such as the trending cartoons or the figure they know to attract their attention and grow their interest in the application.
Usability Heuristics for Mobile Application (7): Flexibility and Efficiency of Use		
10	Ensure flexibility of navigation for the HI alpha generations in exploring the MSL mobile application	The HI alpha generations are the children that easily get distracted by their emotions. Thus, they need flexibility in the navigation of every task that is assigned to them. For example, the HI alpha generations might get pressured to answer questions they are unfamiliar with. Thus, the MSL mobile application should give the flexibility to skip the questions.
Usability Heuristics for Mobile Application (8): Aesthetic and Minimalist Design		
11	Keep the interface design of the MSL mobile application simple and less crowded to minimize the cognitive ability among the HI alpha generations.	The interface design should be simple and less crowded. According to the experts, having only 5-7 elements within a screen is good for enhancing the cognitive ability among HI alpha generations.
12	The interface's color for the MSL mobile application should be minimal but attractive with a good color combination.	In the context of the HI alpha generations, the interface of the MSL mobile applications should be bright and attractive to attract their attention but less crowded. It is good to have a maximum three-color combination or use the earth tone color suggested by the users' representatives through UCD.

Table 5.5 (Continued)

Usability Heuristics for Mobile Application (9): Help Users Recognize and Recover from Errors		
13	The MSL mobile application should provide the redo and undo button for the alpha generations to recover from mistakes.	The MSL mobile application should provide 'Redo' and 'Undo' buttons to help the HI alpha generations to have a smooth experience using the applications. They tend to make massive mistakes while using the applications and cause frustration.
Usability Heuristics for Mobile Application (10): Help and Documentation		
14	The manuals can be an option for the HI alpha generations to assist them in using the MSL mobile applications.	The video tutorials can be associated with the MSL mobile applications for the HI alpha generations referred to for help.
Usability Heuristics for Mobile Application (11): Selection Driven Commands		
15	The click-and-play functions should be maximized in designing the MSL mobile applications for HI alpha generations.	Optimizing the usage of buttons and providing click-play functions is advisable to avoid the HI alpha generations making massive mistakes when interacting with the applications. The use buttons should be fully utilized according to the functionalities.
Usability Heuristics for Mobile Application (12): Visual Representation		
16	Use more multimedia elements than text and static images in designing the MSL mobile applications since the HI alpha generations rely more on graphics and visuals than plain texts.	The HI alpha generations are attracted more to multimedia elements or visuals such as graphics, video, and animation. Thus, it is advisable to represent the elements in the MSL mobile application with the usage of the multimedia elements to catch their attention and increase their level of satisfaction in experiencing the application.

Then, the proposed design principles of the MSL mobile applications were translated into a semi-working prototype for validation through the prototyping method. The process involved was discussed in the next chapter.

5.7 Chapter Summary

This chapter explains one of the validation approaches that has been carried out to validate the proposed design principles of the MSL mobile applications identified in the previous chapter. The expert review method was adopted to validate the proposed design principles. Five experts were chosen to review and validate the proposed design principles. A checklist consisting of the sixteen proposed design principles mapped with NMDG was sent to the experts through their official email addresses. Then, the results were reviewed and analyzed, along with additional feedback and comments. At the end of this phase, the proposed design principles were successfully validated through the expert review method. The next chapter discusses the development of the prototype of the MSL mobile application based on the proposed design principles.

CHAPTER SIX
PROTOTYPING OF THE MSL MOBILE APPLICATION

6.1 Overview

As discussed in the previous chapter, the experts have successfully validated the proposed design principles of the Malay Sign Language (MSL) mobile application based on Nielsen's and Molich's Design Guidelines (NMDG) method. In this chapter, the proposed design principles were validated through the second validation method, which is the prototyping method. This interprets that, to ensure that the proposed design principles are useful and reliable, they must be visualized into a working prototype. The proposed design principles are validated once the prototype has been successfully designed and developed (as desired). This study managed to design one initial low-fidelity prototype and two semi-working prototypes. The processes involved are discussed in the following sections.

6.2 Development of the MSL Mobile Application Prototypes

The prototype is an early version of the developed systems that allow the users to see, interact, and experience the systems or products before being developed into the final product (BenMahmoud, 2020). The prototype is also used to detect and resolve the usability issues that arise a developing the final products. According to Musthafa (2019), resolving and detecting usability concerns during product development is critical to saving time and costs. Changing the prototype is much easier than changing the whole product developed. There are two approaches to creating a prototype, as suggested by BenMahmoud (2020):

a. **Low-Fidelity Prototype:** It is a method of visualizing the ideas of the products through low-fidelity representations such as sketches and drawings on paper or computers without any interactions allowed or more like the static images representing the product designs (Musthafa,2019).
b. **High-Fidelity Prototype:** It creates a fully or partially working prototype that resembles the real final products but with specific constraints. It is designed with design software such as Adobe XD.

Accordingly, most researchers adopt the low fidelity prototype in designing an initial prototype since it is fast, cost-effective, and time-saving and works well with short iterations. Hence, this study manages to design and develop three MSL mobile application prototypes that serve different purposes. One of the prototypes is the initial low-fidelity prototype, further discussed in the following section.

6.3 Initial Prototype of MSL Mobile Application

The MSL mobile application's initial prototype was developed to depict the design principles proposed by user representatives during UCD activities, as mentioned in Chapter 4. Accordingly, the initial prototype was designed in Canva free online software. The prototype follows the actual size of the mobile devices with 600 x 1024px and 170ppi. All photos, videos, and audio used from Google were downloaded from free shared sites to prevent violating user rights. Next, the prototype was converted into pdf format for sharing and presentation purposes. The prototype design underwent several iterations until the

intended design principles could be confirmed. The prototype design sample is shown in Appendix F. After the users' representatives had confirmed the design principles, a semi-working prototype was developed based on the final design of the initial prototype, which was further discussed in the following section.

6.4 Semi-Working Prototype of MSL Mobile Application I

A semi-working prototype of the MSL mobile application was designed and developed based on the sixteen proposed design principles identified in Chapter 4. The prototype was designed with the free online software named 'MarvelApps.' The rationale for choosing this software is because it is easy to use and cost savings since it is free. Besides, it enabled the designers to design the prototype interactively in various device sizes and types by providing ready-made templates. Thus, it can save the designers time in designing the prototype.

Next, this prototype offers dual languages, which are Bahasa Malaysia and English, as suggested by the previous researchers, as mentioned in Chapter 2. The learning contents were designed based on the textbooks to ensure it follows the standard of education in Malaysia. A model was hired for sign language learning content video recording to ensure the originality of the prototype. The sample of the prototype design is attached in Appendix G.

This prototype has undergone testing through a pilot test that was conducted with actual users, the HI alpha generations, as mentioned in Chapter 7. Before the actual testing, the purpose of testing this prototype was to get early input from the intended users. As a result, this prototype needs to be re-design due to the issues and problems arising from the pilot test. Thus, the second design of the semi-working prototype was developed and is further explored in the section below.

6.5 Semi-Working Prototype of MSL Mobile Application II

The MSL mobile application prototype's second version was created utilizing feedback and suggestions from actual users. This prototype was likewise made using "MarvelApps," much like earlier ones. However, this prototype was created exclusively in Bahasa Malaysia, as opposed to the previous version, which offered both Bahasa Malaysia and English. Also, the users' representatives emphasized how important it was for all HI students in Malaysia to be fluent in Bahasa Malaysia because it is the language used daily for learning and communicating in schools. The video learning provided in this prototype was created by the teachers of Sekolah Pendidikan Khas Sungai Petani Kedah, Malaysia. It ensures that the learning contents in this prototype follow the Malaysian education standard that the Ministry of Education Malaysia has enforced. The videos were recorded, edited, and uploaded to the school's YouTube channel. It is free to share and use for educational purposes. Further descriptions of both versions of the prototypes, along with the design principles and NMDG, were discussed as follows:

Usability Heuristics NMDG 1: Visibility of System Status

Design Principle 1: All screens should be provided with the instructions for the HI alpha generations to be aware of their current states.

The title and instructions are on every screen of the MSL mobile application prototype, shown in Figure 6.1. It was written in simple text using different colors. To avoid confusion among the HI alpha generations, the titles of the learning categories and the instructions are distinguished in this way. The teachers of the HI alpha generations requested that the titles and instructions be written in Bahasa Malaysia.

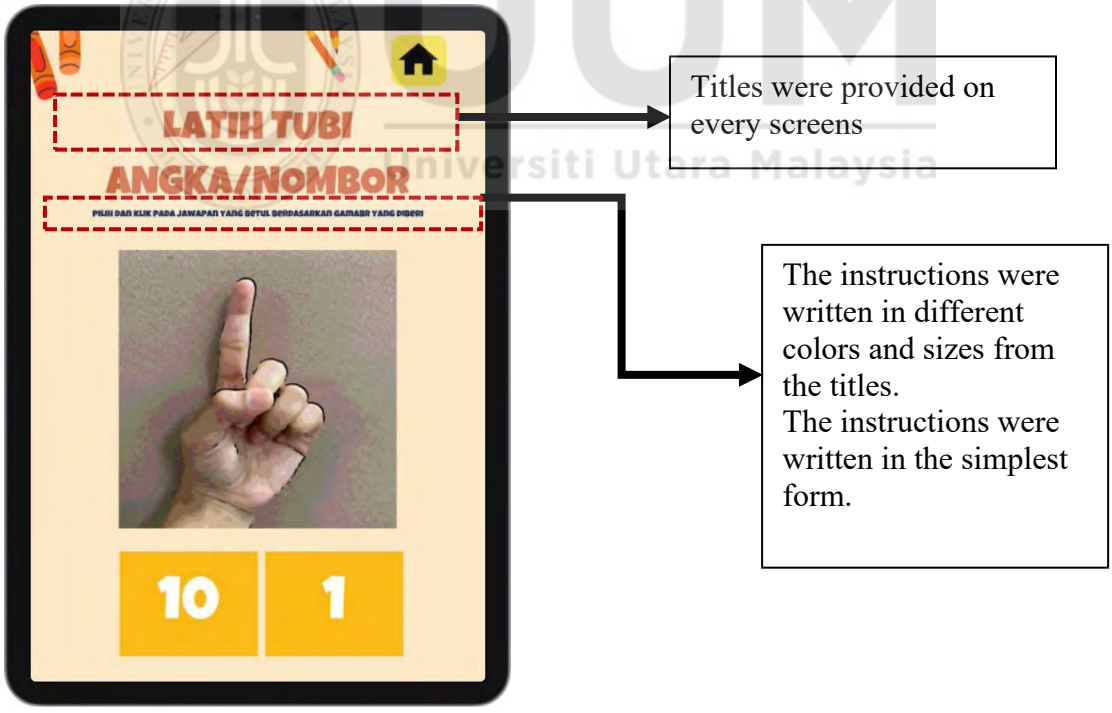


Figure 6.1. Instruction provides

Usability Heuristics NMDG 2: Match between System and Real World

Design Principle 2: The sign language learning contents provided should follow the local education standards for the HI alpha generations.

The "Kod Tangan Bahasa Malaysia (KTBM)" was used to create this prototype. It is a formal and accepted sign language taught by teachers. Additionally, the teachers' textbooks and videos were used to create the teaching content for this prototype. The research team had previously recorded and produced the video learning offered in the previous prototype. As a result, the video learning's contents contain numerous mistakes and deviate from the expected study material. It is essential to adhere to the typical learning materials to ensure that this prototype can stimulate the cognitive abilities of the HI alpha generations. The contrasts in the learning materials presented by the two prototypes are shown in the red box, as illustrated in Figure 6.2.

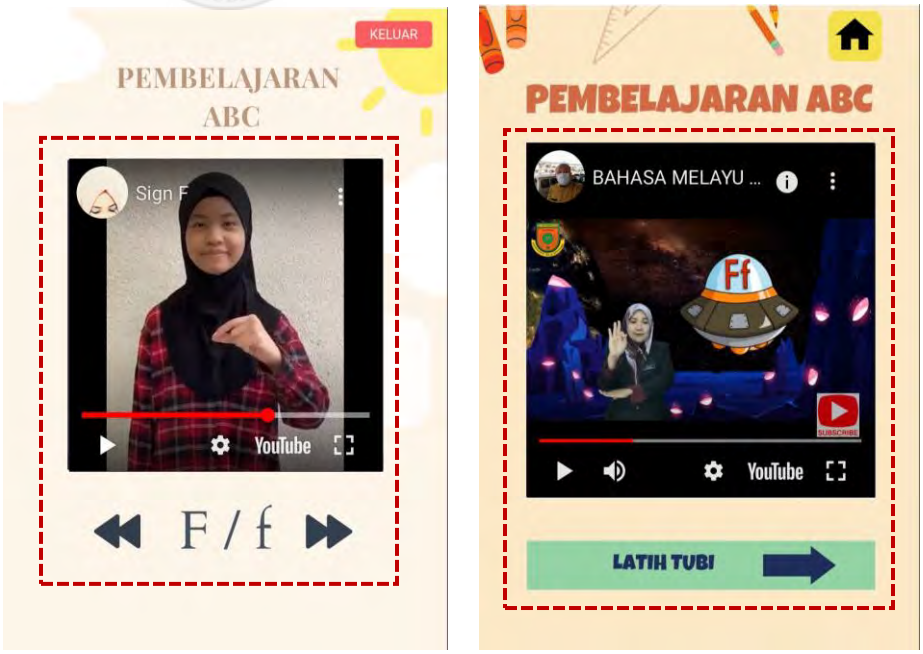


Figure 6.2. Learning contents

Usability Heuristics NMDG 3: User Control and Freedom

Design Principle 3: The MSL mobile applications should allow the HI alpha generations to leave the applications anytime.

Figure 6.3 illustrates how this prototype offers two exit functions for the users. Firstly, the yellow button, which is the 'Home' button. Users can exit their ongoing tasks by using this feature, which directs them to the application's home page, where they can select other tasks to complete. The rationale for providing only a home button for exit on all screens except for the home page is to motivate the users to explore more on the MSL mobile applications through the various categories offered on the homepage. Next, the "X" button was available on the homepage but was red. This allows users to quit using the MSL application and stop working on projects. The sample of the button is shown in the marked red box.

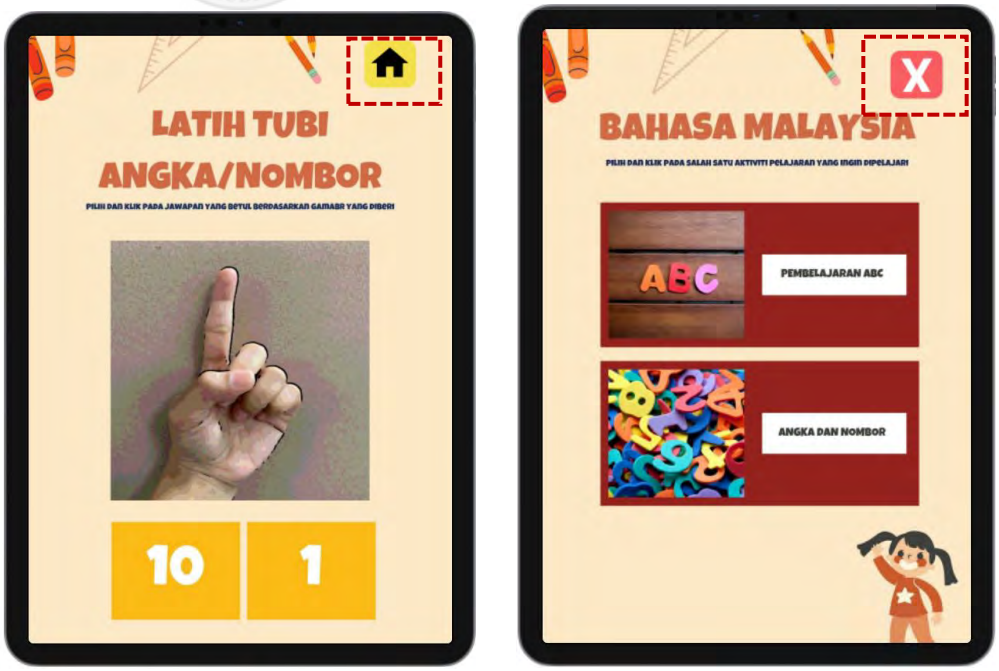


Figure 6.3. Flexibility of application

Usability Heuristics NMDG 4: Consistency and Standard

Design Principle 4: The quizzes or exercises provided must be coherent with the contents of the video learning.

This prototype offers additional exercises to assess the cognitive ability among the HI alpha generations. The contents of the exercises are similar to the videos provided, as marked in the red dotted line. This is to avoid the user's loss and confusion. The exercises were given in static images, and the users needed to click on the button with the correct answers. Figure 6.4 illustrates the video learning contents and the exercises provided.

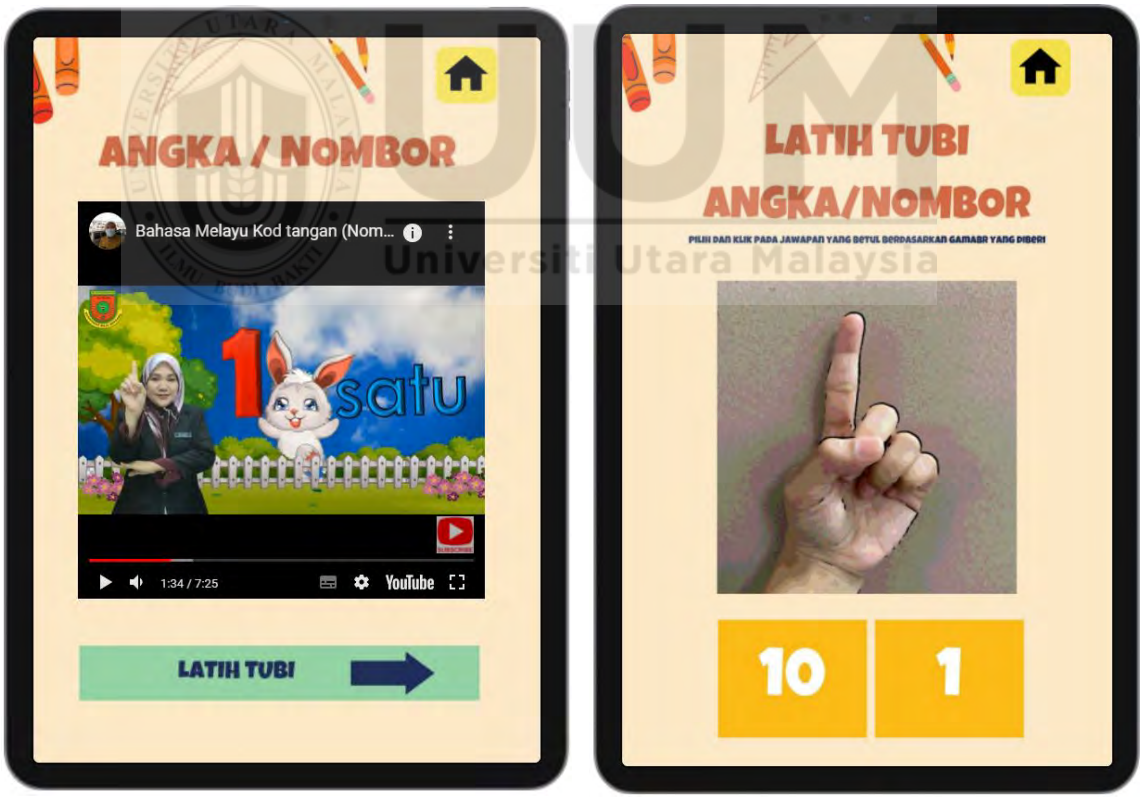


Figure 6.4. Learning videos and exercises

Design Principle 5: The fonts used for the texts in the MSL mobile applications should follow the local education standard font types and sizes.

Prior to this, the previous prototype did not use the standard font recommended by the users' representatives. As a result, during the pilot test, users had trouble reading the instructions. Then, the new prototype was revised to adhere to the standard size the users' representatives recommended and employ the Comic Sans font style. The differences between the prototypes are depicted in Figure 6.6.

Figure 6.5. Example of font style and size

Design Principle 6: The sizes and quality of the graphics, videos, and animations provided in the MSL mobile applications should be maximized and consistent.

As demonstrated in Figure 6.6, the quality of the videos and images in this prototype has improved to be better than in the previous prototype. Every image used was taken and then instantly uploaded into this prototype. The quality of the image could therefore be maximized as a result. Additionally, the animated figure utilized in this prototype was created online using Canva and downloaded in JPEG format. Thus, the quality of all uploaded images and videos in this prototype was set to its highest setting to ensure the quality of the prototype.

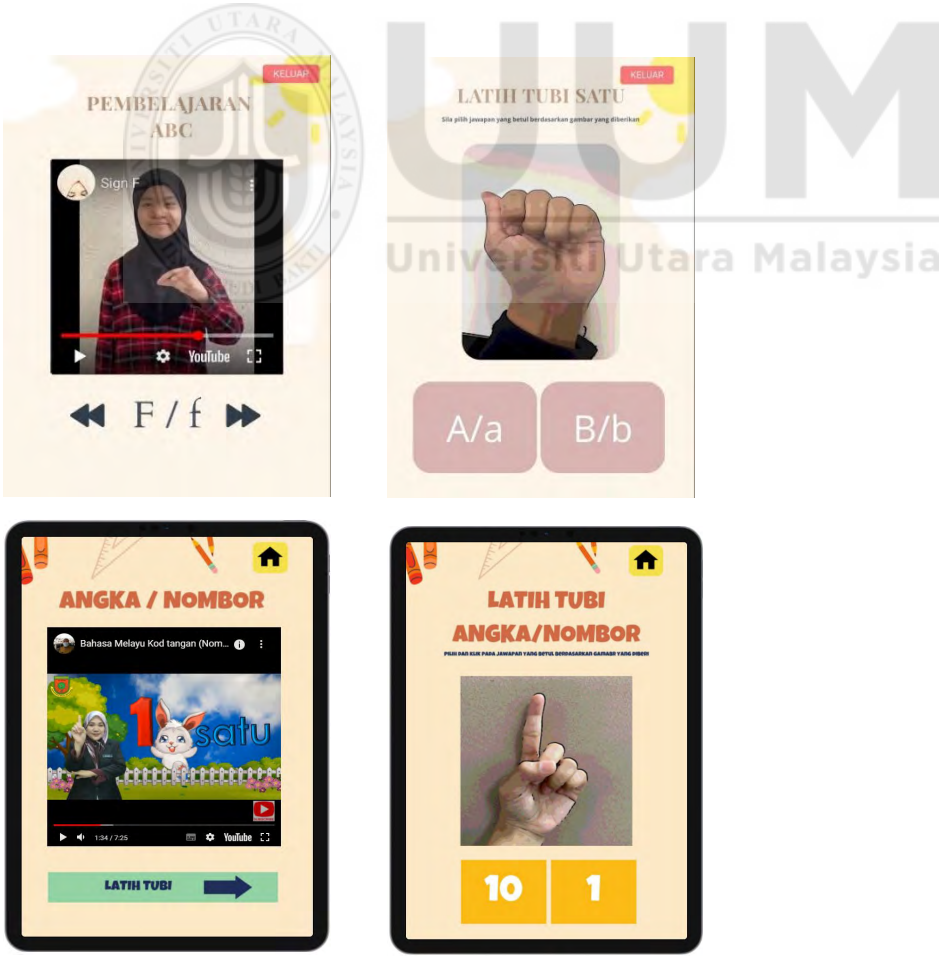


Figure 6.6. Quality of images and videos in prototype

Usability Heuristics NMDG 5: Error Prevention

Design Principle 7: Timely feedback should be provided in the MSL mobile applications through the pop-out dialogue to catch the attention of the HI alpha generations.

To avoid the HI alpha generations from making massive mistakes, timely feedback was provided in this prototype through the pop-out dialogue, as illustrated in Figure 6.7. This pop-out dialogue was explicitly designed to attract the users' attention and notify their exercises' results. The pop-out dialogue with green color will notify them that they have answered the questions correctly and can choose whether they want to continue answering the following questions or go back to the previous ones. At the same time, the pop-out dialogue with red color was designed to notify that they had wrongly answered the questions. Minimal options were given to prevent them from making massive mistakes.

Figure 6.7. Pop-out dialogue to prevent error

Usability Heuristics NMDG 6: Recognition rather than Recall

Design Principle 8: The button in the MSL mobile application should be clickable and consistent according to the functionalities.

The HI alpha generations entirely rely on visuals rather than simple textual. This was demonstrated in the pilot test when users enquired as to the purpose of the buttons in the previous prototype. Consequently, the HI alpha generation teachers proposed making the button utilizing the symbols. To make it simpler for users to comprehend what each button accomplishes immediately, the new prototype has been redesigned, with all buttons now bearing the arrow symbol. The button differences between the two prototypes are depicted in Figure 6.8 (as shown in the red box).

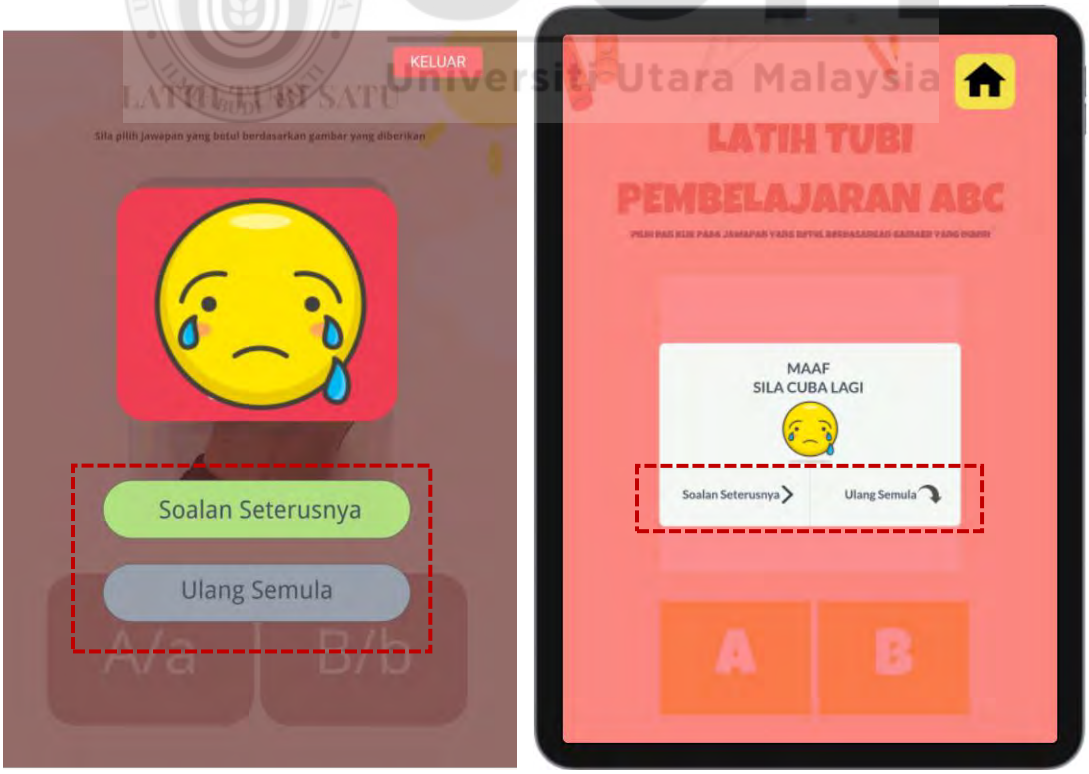


Figure 6.8. Button with symbol

Design Principle 9: The characters used in designing the MSL mobile applications should be recognizable and suitable to the contexts of the HI alpha generations.

When creating an application's user interface, it is imperative to consider HI learners' preferences, especially those of the alpha generations. According to the teachers of the HI alpha generations, when the learners recognize something they have before seen, they get excited and intrigued right away. Previously, the prototype's video learning was designed without other elements rather than the model showing the sign language. The prototype was redesigned to draw users, including additional figures, animals, and spacecraft. Figure 6.9 illustrates the changes between the two prototypes, as shown in the red box.

Figure 6.9. Familiar characters used in the prototype

Usability Heuristics NMDG 7: Flexibility and Efficiency of Use

Design Principle 10: Ensure flexibility of navigation for the HI alpha generations in exploring the MSL mobile application

A high level of flexibility is required for the users to have a smooth experience while navigating the application. Users were previously unable to skip questions they did not wish to answer on an earlier prototype. In contrast, the new prototype allows users to skip questions to boost user satisfaction. According to their teachers, they require flexibility because they are quickly influenced by the emotions of anything they were made to perform. A sample of the screen for each prototype is shown in Figure 6.10. The differences between the two prototypes are shown in the red box.

Figure 6.10. Efficiency and flexibility

Usability Heuristics NMDG 8: Aesthetics and Minimalist Design

Design Principle 11: Keep the interface design of the MSL mobile application simple and less crowded to minimize the cognitive ability among the HI alpha generations.

The academicians have recommended having only 5-7 elements per screen to reduce the cognitive load for the HI alpha generations. This encourages them to use their memory for the information presented on a single screen. These ideas were applied in the earlier prototype as well. Screens are depicted in examples in Figure 6.11.

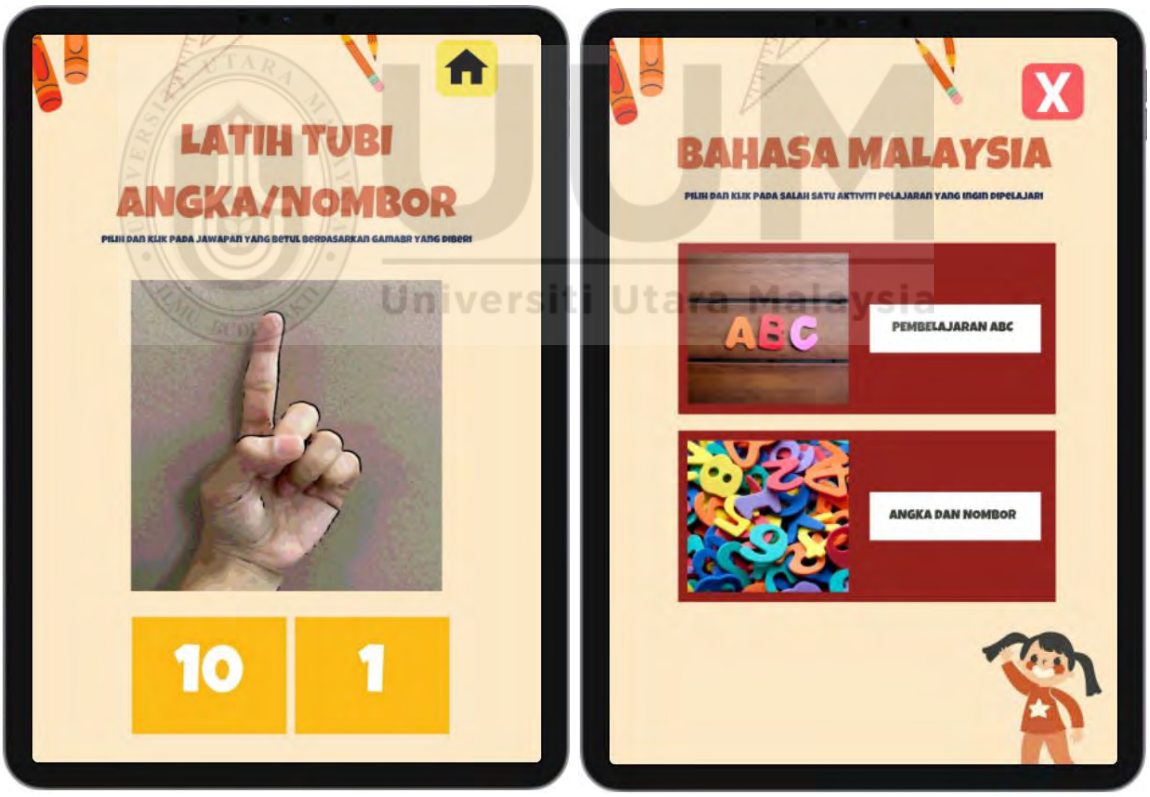


Figure 6.11. Minimal interface design

Design Principle 12: The interface's color for the MSL mobile application should be minimal but attractive with a good color combination.

Since the previous prototype's background was a pale tone and made the interface appear unattractive to users, it has been completely redesigned. During the pilot test, the users and their teacher recommended using an earth tone color to make it look more pleasant. To make it appear better, the cartoon characters should also be included. The changes in the backgrounds between the prototypes are depicted in Figure 6.12.

Figure 6.12. Background color of the prototype

Usability Heuristics NMDG 9: Help Users Recognize and Recover from Errors

Design Principle 13: The MSL mobile application should provide the redo and undo button for the alpha generations to recover from their mistakes.

Initially, the previous prototype lacked features that let consumers fix their errors. The prototype was then updated, as indicated by the red line in Figure 6.13, by adding a button and pop-out dialogue allowing users to confirm their actions.

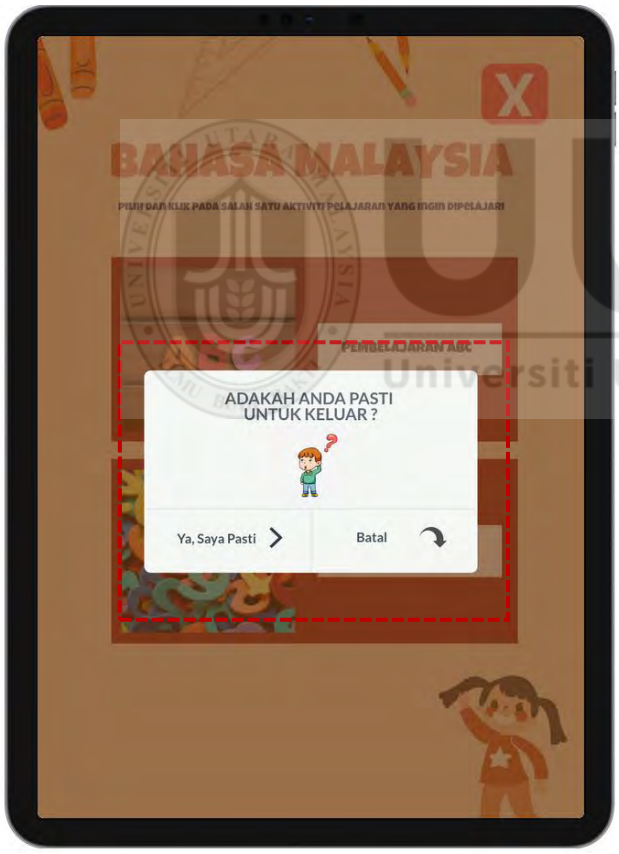


Figure 6.13. Help users recover from errors

Usability Heuristics NMDG 10: Help and Documentations

Design Principle 14: The manuals can be an option to be provided for the HI alpha generations to assist them in using the MSL mobile applications.

As suggested by the experts in the expert review activities, the instructions might be made available as an alternative for the HI alpha generations to use if they require assistance. In the previous prototype, the same idea had been used, and during the pilot test, the actual users had looked up information in the manual before beginning to use the prototype. The teacher additionally concurred that the manual should be provided in video form because children can understand the instructions quicker in a video than they can in a text-based manual. The differences between the screens of the two prototypes are depicted in Figure 6.14.

Figure 6.14. Video tutorial

Usability Heuristics NMDG 11: Selection Driven Commands

Design Principle 15: The click-and-play functions should be maximized in designing the MSL mobile applications for HI alpha generations.

As the users' representatives suggested, click-and-play features were included for all activities. This is done to prevent users from making grave errors that may cause frustration when using the application. The previous prototype also adopted this idea. The screen for the activities is shown in Figure 6.15.

Figure 6.15. Click-and-play functionalities for exercises

Usability Heuristics NMDG 12: Visual Representation

Design Principle 16: Use more multimedia elements than text and static images in designing the MSL mobile applications since the HI alpha generations rely more on graphics and visuals than plain texts.

The multimedia features or visuals, such as graphics, video, and animation, are more attractive to the HI alpha generations. The differences between the two prototypes' video learning are depicted in Figure 6.16. In the past, video learning was simple and limited to the model displaying the sign. The video learning in the new prototype focused on animations, sounds, texts, and pleasing color schemes that may draw consumers in.

Figure 6.16. Visuals representation

In conclusion, the proposed design principles were successfully validated using the prototyping approach with the development of the MSL prototype. Besides, the prototype has been re-design based on the feedback and suggestions made by the teacher and actual users during the pilot test, as discussed in Chapter 7. It was thus established that the suggested design principles were trustworthy when designing the MSL mobile application for HI learners, particularly the HI alpha generations. The last validation approach, user experience testing, covered in the following chapter, was used to validate the proposed design principles.

6.6 Chapter Summary

This chapter discusses the procedures involved in the prototyping approach to validate the proposed design principles for the MSL mobile application. The MSL mobile application prototype was created for this study with the primary goal of verifying design principles. It was created and developed in accordance with the proposed design principles for the MSL mobile application, which were built using the UCD approach as stated in Chapter 4. Three prototypes were designed, each with a different purpose. The prototype eventually becomes usable for gathering information during the anticipated user experience testing. The produced prototype must be used to assess whether the MSL mobile application design principles can meet the needs of the actual users, as stated in the second objective. Chapter 7 discussed the user experience testing was carried out with the actual users.

CHAPTER SEVEN
USER EXPERIENCE TESTING ON THE MSL MOBILE APPLICATION

7.1 Overview

Chapters 1 and 2 explain the difficulties that the hearing-impaired (HI) alpha generations encounter when using the current Malay Sign Language (MSL) mobile applications to support their educational pursuits. The extended Nielsen's and Molich's Design Guidelines (NMDG) by Kumar (2019) were used to construct the design principles of the MSL mobile application for Hearing-Impaired (HI) alpha generations through User-Centered Design (UCD) approach as a solution, as discussed in Chapter 4. Expert review, prototyping, and user experience testing are the three validation methods used to verify the proposed design principles. Previously, the proposed design principles have been validated through expert review (Chapter 5) and prototyping (Chapter 6) approach. Consequently, in achieving the second objective of this study, this chapter discusses the last validation approach, user experience testing.

7.2 Special Requirements on User Experience Testing with HI Alpha Generations

Involving people with disabilities (PWDs) as the primary subjects of the study may be a challenging task for the researchers as they need to think creatively to adopt the multimethod and flexible approach by considering the subjects' abilities (Shaw, 2011). Besides, special consideration should be taken, especially when dealing with the PWDs, particularly the HI alpha generations, since they have difficulty utilizing their hearing organ

to obtain auditory input and output (Bala, 2020). Additionally, due to literacy issues, some HI learners have difficulty interpreting written information (Mich, 2011). They rely a lot on visuals rather than sounds or plain texts. This implies that giving them a voice or written instructions is pointless because they cannot comprehend them.

Moreover, the HI alpha generations are the children just starting to acquire sign language skills to convey their thoughts to the listeners (Bala, 2020). As a result, individuals find it difficult to express their actual emotions and thoughts through sign language. According to Riihiaho (2017), a realistic and natural method, such as observation, can get feedback from HI individuals through everyday activities. Additionally, two essential steps must be carried out before the testing begins, which are (i) the test team itself needs to introduce the product to the subjects and (ii) directly interact with the subjects on the instructions for the activities that need to be accomplished by the subjects. Furthermore, Cano (2018) suggested using three observing and informative methods presented in Table 7.1 to obtain the respondents' spontaneous feedback.

Table 7.1

Suggested Observing and Informative Method for User Experience Testing by Cano (2018)

Observing and Informative Method			
No	**Method**	**Advantages**	**Disadvantages**
1	Direct Observation	It does not require verbal feedback from the subjects, as the input can be seen directly through the expressions and ways of completing the tasks.	The shy subjects might give false feedback as they are uncomfortable completing the tasks.
2	Thinking Aloud	They can present their feedback and views verbally while completing the tasks.	It is unsuitable and can be very challenging for subjects unable to speak or express their feelings through sign language.
3	Wizard of Oz	It is observational and informative. The subjects only need to complete the tasks and do not have to give feedback on their experience.	The assistants must regularly check on the subjects to ensure they do not lose motivation.

There are three types of observing and the informative method suggested by Cano (2018) that could be adopted in user experience testing with the HI learners, which are (i)direct observation, (ii)thinking aloud, and (iii)wizard of oz, as tabulated in Table 7.1. These methods allow the observers to observe the subjects' behaviors towards the system or products created naturally.

According to Cano (2018), choosing the best approaches for conducting user experience testing depends on the level of abilities of the subjects. Additionally, when it comes to HI individuals' involvement, the researchers should refrain from employing procedures that

require simultaneous actions from the subjects, such as having them complete the tasks while verbally providing feedback to the observers. This is because the distractions cause the individuals to provide erroneous feedback when expressing it frequently. As a result, this study cannot use the thinking aloud method since it demands the participants to carry out two activities simultaneously (using the applications and making vocal remarks). Next, the wizard of oz method focuses only on observation and does not require the subjects to provide feedback. However, the research team needs to check on the subjects frequently to ensure they can focus on completing the tasks. Nonetheless, this approach is ineffective because HI students are easily distracted by others around them, leading to frustrations (Cano,2018).

As a result, this study decided to opt for the last method, direct observation. It does not require a verbal response and lets users interact with the products freely. They can freely start, stop, and resume the testing within the time provided. Additionally, it could be used with other techniques for eliciting feedback. The section that follows provides more details on the method that was selected.

7.3 Direct Observation

Direct observation is one of the qualitative approaches that use the natural ways of approaching the actual users or subjects involved in the testing to obtain direct and spontaneous feedback through their natural behaviors, as mentioned in Chapter 3. This study manages to conduct one pilot test and two direct observation sessions with the

selected HI alpha generations as actual users to seek user experience findings on the prototype of the MSL mobile application and to increase the credibility, validity, and reliability of interpretation of findings. Figures 7.1 and 7.2 illustrate the activities, objectives, and observations' outcomes in the appropriate ways.

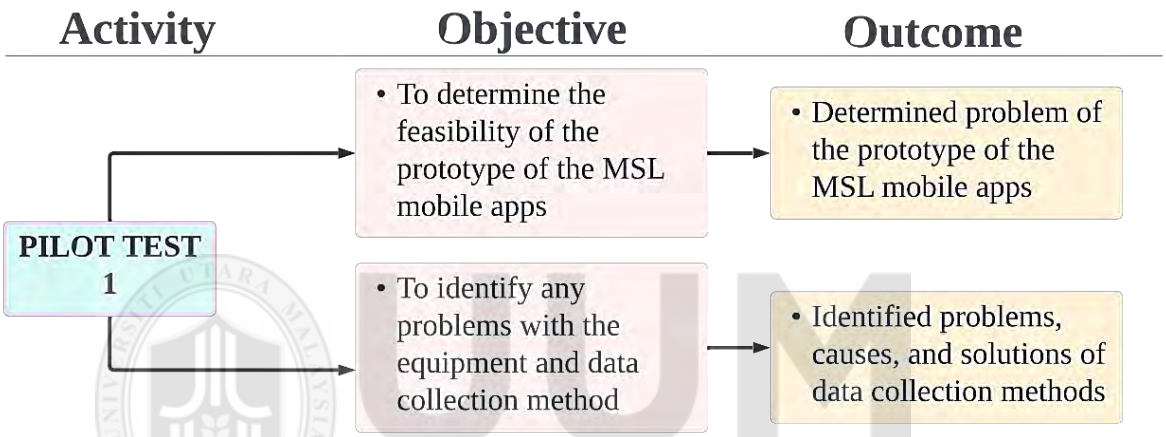


Figure 7.1. Pilot Test

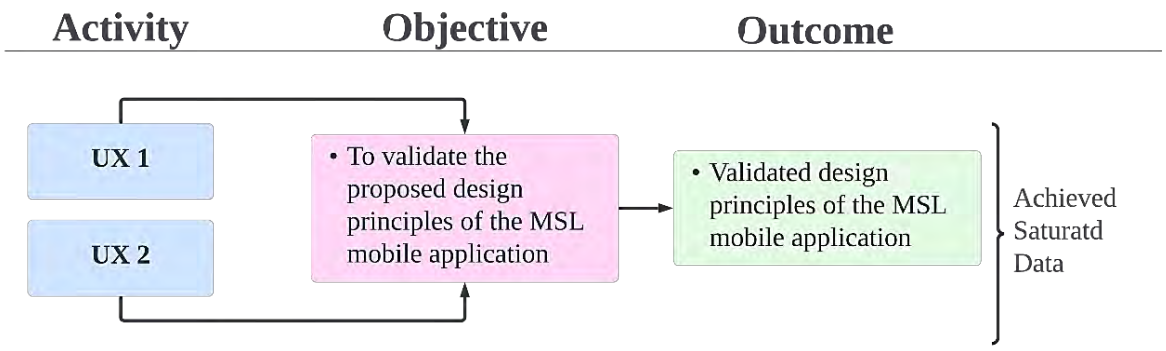


Figure 7.2. Two Cycles of User Experience Testing (UX)

The pilot test was carried out with the HI alpha generations to determine the prototype's feasibility and identify any problems with the equipment and data collection methods. At

the end of this pilot test, the problem of the prototype, equipment, and data collection methods was identified and recovered. Then, two direct observation sessions were conducted in a different procedure to obtain saturated results. Having replication in both ensures the findings are reached too comprehensive and complete. The following section extensively discusses the activities involved during the pilot testing.

7.4 Pilot Test

Prior to the actual user experience testing, a pilot test was carried out with the actual users. The purpose of the pilot test with HI alpha generations in the qualitative approach is different than in the quantitative approach. In this study, a pilot test was carried out with the primary objective of investigating the wellness and consistency of user experience testing. Meanwhile, the specific objectives are (i) to determine the feasibility of the prototype of the MSL mobile application and (ii) to identify any problems with the equipment and data collection methods. This is crucial in determining if there are flaws, limitations, or other weaknesses in the prototype of the MSL mobile application, equipment, or data collection method, allowing this study to make necessary revisions before commencing the actual user experience testing. The methods and procedures involved were discussed in the following sub-sections.

7.4.1 Methods and Procedures

The pilot test was conducted with five selected HI alpha generations from Sekolah Kebangsaan Pendidikan Khas Sungai Petani, Kedah, Malaysia. The ages of the subjects

are between nine to twelve years old. Three of the subjects were females, while the remaining were males. The reasons for scoping the range of ages below 12 years old are discussed in Chapter 2. This number is sufficient for a pilot test of qualitative research to represent the population of low vision learners locally or broadly, as they are homogenous subjects.

Subjects were expected to feel comfortable in their natural environment, such as their classroom. Accordingly, the test was conducted in their classroom to ensure they felt comfortable. The test was segmented into four segments which are (i) introduction, (ii) observation, (iii) group discussion, and (iv) closing. Before testing commenced, one laptop was set up with the prototype of the MSL mobile application. The video, audio, and recording sheets were prepared to record the observation and group discussion. Additionally, one assistant was hired to assist with the testing, and two teachers were hired as translators.

After the equipment had been set up, the subjects were asked to sit in a group, and one laptop was attached to them, as shown in Figure 7.3. Before the test was started, the subjects were introduced to the research team and the purpose of this study by their teachers through sign language communication. After the introduction ended, the subjects started to experience the prototype. The direct observation method was utilized where the research team recorded their behavior towards the prototype. The subjects only took 10 minutes to finish exploring the prototype.

Figure 7.3. Subjects Involved in Pilot Testing

Then, the subjects were asked to sit in a group with their teacher and the research team for a group discussion session. The teachers asked for their opinion and feedback on the prototype. They use sign language to communicate. The teachers then translate the sign language into simple verbal communication with the research team. Having finished this session, the session was closed by thanking and giving a token to the subjects. The following sections discuss the results and findings of the pilot study.

7.4.2 Results and Findings

The methods and procedures employed during the pilot test have been thoroughly detailed in the previous section. The outcomes of the pilot test were analyzed from two distinct

viewpoints, including (i) problems with the prototype of the MSL mobile application and (ii) problems with the data collection method.

7.4.2.1 Problems with MSL Prototype

The prototype of MSL mobile applications was completed in a month with the involvement of the users' representatives. There was expected to be no problem with the prototype after quality checking. However, the use of the prototype revealed several "bugs" that needed to be attended to. The problems were listed as follows:

i. **Navigation Error:** When students click on the "Pembelajaran ABC" learning category, they are taken to the "Angka dan Nombor" website instead of the intended page. The subjects were, therefore, confused.
ii. **Unclickable Button:** The subjects were frustrated because several buttons, like "Next" and "Previous," could not be used.
iii. **Low Timing Transition:** The timing transition needs to be improved to make it more exciting.
iv. **Unsuitable Screen Resolution:** The prototype was created with the design of mobile devices' screen sizes in mind, yet the subjects access it using laptops. As a result of the screen size issue, people cannot see the application well.

Moreover, some of the prototype's design and functionality fail to meet user expectations and proposed design principles. As a result, the prototype was revised considering the comments and ideas raised by the subjects and teacher during the group discussion—

chapter 6 covered how the prototype's design and features were improved. Nevertheless, the research team was aware of all the issues so they could be fixed in time for the main testing.

7.4.2.2 Problems with Data Collection Method

The pilot test also identified certain issues with the equipment set, especially with the data collection methods, which hamper the efficiency of the user experience testing. In Table 7.2, all issues with data gathering techniques are listed along with their causes and fixes.

Table 7.2

Problems, Causes, and Solutions Detected in Pilot Test

No	Problems	Causes	Solutions
1	Only two subjects showed excitement in experiencing the prototype, while others showed uninterested emotions in joining the testing.	Access to the devices was limited during group testing because the research team provided just one laptop for a group with many users.	The testing should be done in groups and individually, with each group containing a maximum of three individuals for one device.
2	Low internet connection.	Internet connectivity issues at the school.	The research team should prepare alternatives or choose the right place with good internet connectivity, such as a computer lab.
3	A video camera's memory was not enough to record the whole session.	The memory card did not have enough memory.	Prepare extra devices or memory cards for backup.
4	Problems in organizing tasks.	Have only one assistant.	Hire more assistants according to the tasks.

Table 7.2 (Continued)

5	The subjects had difficulties conveying their thoughts through sign language.	Lack of skills in interpreting their thoughts through sign language representation.	Use another method to elicit feedback, such as visual representation like smileys or flashcards.

The subjects enjoyed exploring the prototype with their friends throughout the pilot test. Still, due to the big group situation, there was little possibility for each subject to use the prototype. As a result, two subjects showed little interest in taking the test. Thus, the teacher advised breaking the group into smaller groups of no more than three people. To guarantee they had a chance to test the prototype, the research team may also undertake the test separately with the devices attached. Additionally, an issue with the internet connections leads the prototype to stop working while testing abruptly. It is suggested that the research team prepare many options to ensure consistent internet connectivity throughout the testing process.

The research team should improve the planning stage to address the issue of insufficient memory for recording and assistance. Then, for the feedback elicitation method, it is advisable to use visual representatives such as smileys or flashcards. This is because the subjects are children just starting to acquire the skills of using sign language to convey their thoughts. Thus, they have a hard time speaking their mind. Besides, the results tend to be biased since it requires the third party, the teacher, as the translator, to translate the feedback. The justifications of the results were discussed in the following sub-section.

7.4.3 Justifications of Results and Findings

Based on the pilot test that has been conducted, rich experience and information were gathered as guidance for this study to show actual research of user experience testing. It was found that this testing should be conducted in a group of a maximum of three people per group. This ensures that all subjects can use the prototype with their partners. Additionally, group discussions should not be used to gather feedback from the subjects. Since the feedback was not obtained directly from the individuals but required translation, this method tends to provide biased results. This will impact the results' validity and dependability. Thus, it is suggested to use the methods that require direct feedback from the subjects with the assistance of visuals such as the rating method through smileys or flash cards that represent their natural feelings. Lastly, the problems that arise during the pilot testing should be noted for enhancement during the leading testing, as discussed in the following section.

7.5 User Experience Testing

As mentioned earlier, the user experience testing was carried out with the HI alpha generations to validate the proposed design principles of the MSL mobile application constructed in Chapter 4. Two direct observations were conducted (group and individual). The demographic of the subjects chosen was discussed in the following subsections.

7.5.1 Demographic of the Subjects

Six HI learners from Sekolah Kebangsaan Pendidikan Khas Kedah, Malaysia were chosen. The students were divided into three males and three females, ages seven to eight. Table 7.3 describes the subjects' demographics. The table highlights the age, gender, class level, levels of understanding sign language, categories of hearing loss, and levels of using mobile devices.

Table 7.3

Demographics of subjects involved

Subjects	Age	Gender	Class Level	Levels of Understanding Sign Language	Categories of Hearing Loss	Levels in using a mobile device
Subject 1	7 Years Old	Male	Level 2	Low	Total	Good
Subject 2	8 Years Old	Male	Level 2	Medium	Total	Good
Subject 3	7 Years Old	Male	Level 2	Low	Total	Good
Subject 4	8 Years Old	Female	Level 2	Medium	Partial	Good
Subject 5	8 Years Old	Female	Level 2	Medium	Partial	Medium
Subject 6	7 Years Old	Female	Level 2	Low	Partial	Good

Table 7.3 tabulated the personal information of the chosen subjects involved in the testing. There are six HI alpha generations chosen by the teacher, according to Riihiaho's (2018) recommendation that teachers are valuable assistants in selecting appropriate test participants. Three of them are male students with total hearing loss, and the remaining are female students with partial hearing loss. According to the teacher, partial hearing loss

students have around 50% of hearing loss or use assistive devices for hearing. All subjects were chosen from the same level of classes since they have levels of understanding of sign language from low to medium. As for the levels of expertise in using mobile devices, most subjects are good at using mobile devices except for subject 5. Figure 7.4 illustrates the subjects involved in this study. The testing started with a direct observation I, which is the group direct observation that was extensively discussed in the following section.

Figure 7.4. The subjects involved in the testing

7.6 Direct Observation 1

The direct observation I was conducted with two different groups of subjects, male and female groups. The rationale for conducting the testing in a group is to observe the differences between their behavior and reactions towards the prototypes, as well as to

assess their level of understanding of the prototype. The instruments and methods involved are described in the following subsections.

7.6.1 Instruments and Methods

As a kickstart to the testing sessions, an online application was made to the Ministry of Education Malaysia through the Educational Research Application System (ERAS). This is to gain approval to involve the HI alpha generations from the government school. Then, an acceptance letter was given to them as attached in Appendix H. Next, to acquire clearance to perform the testing with the HI alpha generations at school, an official email was written to the director of Jabatan Pendidikan Khas Malaysia. After two weeks, the approval letters were notified and attached through the email reply as attached in Appendix I. Following that, both the approval letter and formal notification letter, as attached in Appendix J sent to the official email of the principal requesting permission to perform testing with the HI alpha generation. Then, the approval notification was received from the principal's email along with the teacher's name in charge. Before the test started, the consent forms attached in Appendix K were given to the selected subjects.

Moreover, a checklist of this testing procedure, rules, and regulations form, as attached in Appendix L, was handed to the teacher. The primary purpose of this checklist is to ensure that this testing process follows the procedures, rules, and regulations highlighted in the list. Next, an evaluation checklist was given to the observers, as attached in Appendix M. At the same time, the teacher briefly introduced the subjects, as shown in Figure 7.5. The

teacher introduced the test team and the purpose of the testing activity to the issues before the testing was started.

Figure 7.5. Introduction Session

Next, the subjects were divided into two groups of three people per group, as shown in Figure 7.6. They were asked to sit next to each other, and they were given the choice of picking their team members. It must be emphasized that getting a natural learning environment setting is vital for this study to obtain truthful results. Next, the subjects were prepared with two tablets, one per group. They were given thirty minutes to complete the tasks assigned. Within the allotted time, the subjects are free to examine the prototype of the MSL mobile application. The results of the direct observation I from the evaluation checklists were discussed in the following sub-sections.

Figure 7.6. Two groups of subjects

7.6.2 Results and Findings

The results of direct observation I from the evaluation checklists were analyzed and discussed as follows:

Design Principles 1: All screens should be provided with instructions for the HI alpha generations to be aware of their current states.

The prototype provides instructions for all screens to prevent the users from being lost in the application. It can be seen through the observation that all subjects read the instructions before clicking the other button to continue their tasks. However, one of the subjects from the male group pointed to the instructions that he did not understand and asked for help from his friend. His friend clearly described the instructions through sign language, making the subject easy to understand as he nodded his head and continued to use the application. Hence, it is suggested by the teacher to provide simple and direct instructions since it will be easier for them to understand. The screen of the prototype is depicted in Figure 7.7 and

includes the participants' responses as well as the instructions that they asked, which are denoted by the red box.

Figure 7.7. Subject asking for help to clarify the instructions

Design Principles 2: The sign language learning contents provided should follow the local education standards for the HI alpha generations.

To avoid misunderstanding, the designers need to ensure that the learning content is designed to follow the local education standard. During the observation, one of the female group's subjects noticed that the alphabet F sign does not resemble the sign they learned as it follows the other version of MSL. Consequently, they are distracted and nearly choose to exit the application. But the teacher asked them to answer it wrongly on purpose and continue to the following questions. However, they show frustration after answering the questions and getting them wrong. Figure 7.8 shows the screen and the response from the subjects.

Figure 7.8. Subject response to the wrong learning content

Design Principles 3: The MSL mobile applications should allow the HI alpha generations to leave the applications anytime.

During the discussions of designing the prototype, the teachers recommend providing an exit button for all screens because the subjects are easily distracted and feel bored. It can

be seen clearly in one scenario where the subjects exit the ABC learning exercises after they have answered one question wrongly. Then, they continue to other sections.

Design Principle 4: The quizzes or exercises provided must be coherent with the contents of the video learning.

This prototype provides two learning activities which are video learning and exercises. From the observation, all subjects from the female group answered the question by referring to the video learning provided, as shown in Figure 7.9. Thus, designing quizzes or exercises similar to video learning is essential to avoid users' confusion.

Figure 7.9. Subjects refer to the video and answer the questions

Design Principle 5: The fonts used for the texts in the MSL mobile applications should follow the local education standard font types and sizes.

As for the font style, it has been proved that they can recognize the letters and numbers in the applications at first glance, read the instructions, and identify the alphabet in the exercises. However, it was suggested by the teacher of the subjects to use bigger fonts for the instructions as the subjects need to zoom in on the texts to read. Figure 7.10 shows the situation where the subject needs to zoom onto the screen to read the instructions.

Figure 7.10. Subjects zoom in to read the instruction

Design Principle 6: The sizes and quality of the graphics, videos, and animations provided in the MSL mobile applications should be maximized and consistent.

When the subjects saw the video learning, they were excited and happy. They even started to recall the sign language they learned at school. Besides, they also interact with the video learning and make the sign language following the video learning. Hence, it is shown that

the HI alpha generations are fully attracted to the characters they are familiar with. Figure 7.11 shows the subjects following the sign shown in the video.

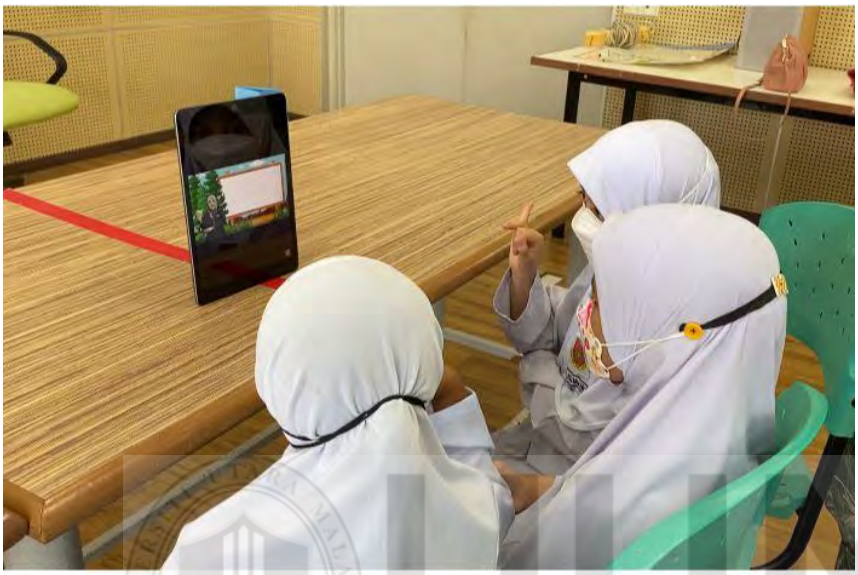


Figure 7.11. Subjects enjoying the video learning

Design Principle 7: Timely feedback should be provided in the MSL mobile applications through the pop-out dialogue to catch the attention of the HI alpha generations.

To prevent the massive errors made by the users, the MSL mobile application provides timely feedback to notify users of every action they have made. Besides, it only requires minimum actions from the users. During the observation, one of the male group subjects accidentally clicked on the wrong answer. The pop-out dialogue showed the red alert indicating the answers were wrong and provided only three buttons which are the replay, next, and home buttons. The subject shows a panicked face and chooses the replay button. Then, the screen shows the question again. He was so happy and clicked on the correct

answer. The subjects laugh and clap their hands when they see green pop out when they get the correct answers. Thus, this shows that the subjects should be given the minimal option to avoid them from making massive mistakes. Figure 7.12 shows the situations during the observation.

Figure 7.12. Subjects happy with the correct answer

Design Principle 8: The button in the MSL mobile application should be clickable and consistent according to the functionalities.

The observation shows that the subjects recognize the button and its functionalities at first glance since they have a smooth experience clicking the button. Besides, all the buttons are clickable and function well. Figure 7.13 shows the subject clicking on the following button.

Figure 7.13. Subjects click on the next button

Design Principle 9: The characters used in designing the MSL mobile applications should be recognizable and suitable to the contexts of the HI alpha generations.

All subjects from the female group enjoyed the video learning until the end and showed the signs along with the video, as shown in Figure 7.14. They are excited to see their teacher as one of the video's characters. Besides, they also show the sign of other elements that they recognize in the videos, such as the cats and the spaceships.

Figure 7.14. Subjects follow the character shown in the video learning

Design Principle 10: Ensure flexibility of navigation for the HI alpha generations in exploring the MSL mobile application

All subjects from the male group chose to skip the videos learning and jump into the exercises provided for both categories. However, they answered all the questions provided without skipping them and replay the questions they answered wrongly. Figure 7.15 shows the subjects' choice to skip the video learning.

Figure 7.15. Subjects skip the video learning

Design Principle 11: Keep the interface design of the MSL mobile application simple and less crowded to minimize the cognitive ability among the HI alpha generations.

One of the academicians advised it through a preliminary interview to only provide 5 to 7 elements per screen to minimize the cognitive load for the HI alpha generations. It was proven that this application could evoke the cognitive abilities of the HI alpha generations

when the male group subjects could remember the sign that they referred to the video to answer the question in the exercise's sections**.**

Design Principle 12: The interface's color for the MSL mobile application should be minimal but attractive with a good color combination.

The female group kept replaying the video learning and showed a happy face when enjoying the video. Besides, the male groups also keep replaying the exercises excitedly. Hence, it can be concluded that the interface and the video learning have successfully attracted the subjects' interests. Figure 7.16 shows the subjects from both groups enjoying the video learning and exercises.

Figure 7.16. Subjects enjoying the prototype

Design Principle 13: The MSL mobile application should provide the redo and undo button for the alpha generations to recover from their mistakes.

During the early observation sessions, one of the subjects in the female group has accidentally click on the exit button at the homepage. However, this prototype has provided the pop-out dialogue for the users to confirm their actions. Then, the subjects click the cancel button and continue experiencing the prototype.

Design Principle 14: The manuals can be an option to be provided for the HI alpha generations to assist them in using the MSL mobile applications.

From the observation, none of the subjects chose the help button to view the manuals. All subjects directly use the prototype and can complete the tasks at first glance. It can be concluded that the subjects were able to explore this prototype independently without the manuals.

Design Principle 15: The click-and-play functions should be maximized in designing the MSL mobile applications for HI alpha generations.

All subjects had smooth experiences when completing the tasks given. They know how to handle the prototype by clicking the button and answering the questions.

Design Principle 16: Use more multimedia elements than text and static images in designing the MSL mobile applications since the HI alpha generations rely more on graphics and visuals than plain texts.

This prototype utilizes multimedia elements by providing learning videos, static images, and colorful texts. All subjects were satisfied with the application as they kept replaying the prototype until the time was over. They even asked for additional time to explore more, as shown in Figure 7.17.

Figure 7.17. Subjects asking for additional time

In conclusion, having tested the prototype in a group, this study found that the prototype of the MSL mobile application could satisfy the subjects' needs as they provided positive feedback towards the prototype. Besides, the prototype meets all the needs of the proposed design principles. Next, the subjects were needed to test the prototype individually through direct observation II, further discussed in the next section.

7.7 Direct Observation 1I

The second direct observation session was conducted to assess the ability of the users to learn independently through the prototype. This session was conducted individually. Besides, this session aims to achieve the saturated data and increase the confidence of the findings. From that, rich and valuable data were elicited through their behavior towards the prototype. The instruments and methods involved were discussed in the following sub-sections.

7.7.1 Procedures and Methods

As in the previous session, this session started with a briefing session by the teacher to the subjects. After the briefing session ended, the subjects needed to sit far from each other and were given a tablet associated with the prototype of the MSL mobile application, as shown in Figure 7.18. The subjects were chosen from two different conditions, which are the female subject with partial hearing loss and the male subject with total hearing loss. The rationale for selecting the subjects from other categories is to achieve saturated results from this observation. To coincide with the aims of this application, which is to deliver a self-learning experience, the test team was prevented from communicating with or disturbing the subjects. This is to avoid getting results that can be considered as bias.

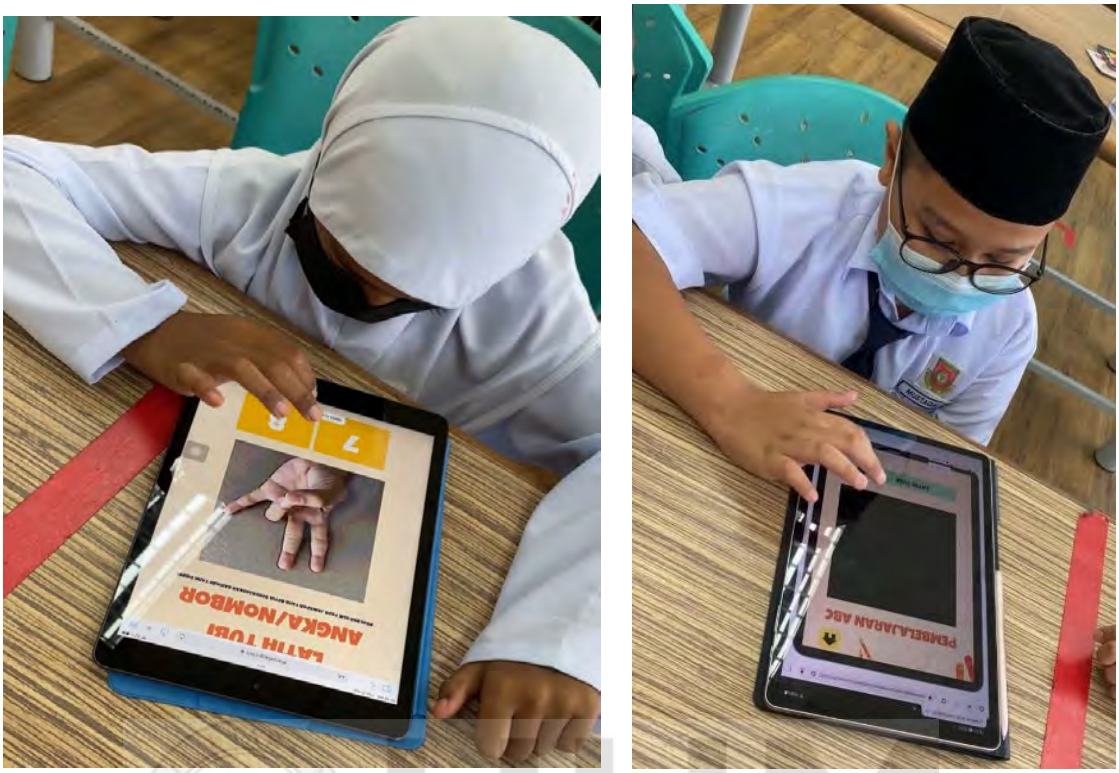
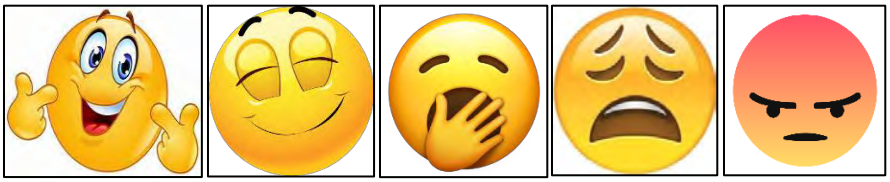


Figure 7.18. Individual testing

Then, the subjects were given flashcards, as shown in Figure 7.19. The smiley means 1) extremely happy, 2) happy, 3) boring, 4) sad, and 5) happy. They need to show the flashcard to indicate their feeling every time they have completed the tasks given. The following sub-section discussed the results and findings of this session.



Extremely Happy Happy Boring Sad Awful

Figure 7.19. Smiley for feelings' representations

7.7.2 Results and Findings

As a result of the individual testing, all subjects fully utilize the 30 minutes given to each to explore the application without distraction. Besides, they could complete all tasks quickly since they could memorize the flow of the application and the answers to the questions asked. However, they still show excitement in the individual testing.

On the other hand, all the female subjects with partial hearing loss were still attracted to playing the video learning and excited to see their teacher as a model. They even follow the sign shown in the video. They can even show the movement by themselves by visiting the alphabet shown. Figure 7.20 shows one of the subjects that show the sign from the alphabet shown in the video. When the subject had finished watching the instructional video, she even displayed an extremely happy smiley to the camera, as shown in Figure 7.20.

Figure 7.20. Feedback from the subjects for the video learning screen

Next, all male subjects with full hearing loss tend not to play the video learning as they choose the exercises category. When they received the correct answers, all participants expressed delight and could recall the solutions to every exercise just as they had done in a direct observation I. As a result, it can be said that this prototype has successfully stimulated the subjects' cognitive abilities because they can memorize the answers to all the questions. The male subject in Figure 7.21 appeared delighted when he correctly identified the question. In addition, two male participants gave the 'extremely happy face' smiley to the camera after completing the tasks, as seen in Figure 7.21.

Figure 7.21. Subjects show happy face for the right answer

Based on the ratings the subjects gave, all subjects showed ‘extremely happy’ smiley face to the camera, recording every task they completed. This indicates that they enjoyed using the MSL mobile application prototype and were satisfied. They also requested their teacher’s permission to revisit the prototype after finishing the testing. This demonstrates that they were drawn to the prototype. The fact that they could use the prototype

independently demonstrates how well it allowed the individuals to learn on their own. The completion and validation of the user experience testing demonstrate that all the goals of this study were met, as well as the construction and validation of the sixteen proposed design principles.

7.8 Chapter Summary

Sixteen design principles of the MSL mobile application for HI alpha generation were successfully constructed based on the NMDG through the UCD approach, as discussed in Chapter 4. Then, the proposed design principles were then validated through expert review and prototyping methods. In this chapter, the proposed design principles were validated through user experience testing involving the users of the HI alpha generations. A pilot test and two direct observation sessions were carried out. After the pilot test, the prototype of the MSL mobile application was re-design due to the problems that arise, and the suggestions made by the subjects and teachers involved to enhance the prototype. Then, six HI individuals were chosen to test the prototype during the main testing. As a result, the subjects were satisfied and happy with the prototype of the MSL mobile application since it provides a smooth experience for them. At the end of this phase, a list of design principles for the MSL mobile application for the HI alpha generations based on the NMDG has been successfully validated and achieved this study's second objective. The next chapter summarizes the thesis by answering the research objective and research questions. Recommendations for future researchers and the limitations of this research are also elaborated.

CHAPTER EIGHT
CONCLUSION

8.1 Overview

The main goal of this study is to form a new set of design principles for the Malay sign language (MSL) mobile application for the hearing-impaired (HI) alpha generations based on Nielsen's and Molich's Design Guidelines (NMDG). The target users of this study are children born after 2010 and have limitations in utilizing their hearing organs, also known as HI alpha generations. Accordingly, this study is carried out based on two research questions as follows:

i. Why are the MSL mobile applications' existing design principles inappropriate for the HI alpha generations?

ii. How to validate the design principles of the MSL mobile application for HI alpha generations?

Hence, to achieve the main goals, two objectives were highlighted as follows:

i. To determine the design principles of MSL mobile application for HI alpha generations through a user-centered design process.

ii. To validate the design principles of the MSL mobile application for HI alpha generations through prototyping, expert review, and user-experience testing.

The following sections provide extensive explanations of the solution proposed for each research question, a discussion on the implications of the study to theory and practical, then end with a discussion of future research and overall conclusions of this study.

8.2 Research Question 1: Why are the MSL mobile applications' existing design principles inappropriate for the HI alpha generation?

Prior to reviewing and analyzing the existing MSL mobile applications currently available in the market, it was found that none of them was hybridizing the NMDG in designing and developing the applications. Most previous researchers suggested hybridizing the NMDG since it could evoke cognitive abilities among the users, as mentioned in Chapter 2. Cognitive abilities allow the users to clearly understand and memorize the learning contents to support their daily life. However, Kumar's (2019) research mentioned that the NMDG developed in 1990 and 1994 by Jakob Nielsen was not considered in the context of mobile applications. Thus, Kumar (2019) has reformed the NMDG by considering the mobile application context. Still, the design guidelines do not consider the context of HI learners, particularly the alpha generations. Therefore, no design guidelines have been devised explicitly for HI alpha generations based on the evolutions of the NMDG discussed in Chapter 2.

Hence, a new set of design principles that considers the needs of HI individuals, particularly alpha generations, were proposed throughout this study. The design principles were proposed through User-Centered Design (UCD) approach, as discussed in Chapter 4.

The users' representatives identified and confirmed six design principles based on the NMDG extended by Kumar (2019). Three validation approaches were carried out to ensure the reliability of the proposed design principles, which are discussed in the following section.

8.3 Research Question 2: How to validate the design principles of the MSL mobile application for HI alpha generation?

The design principles that have been identified and confirmed by the users' representatives were validated through three validation methods which are expert review, prototyping, and user experience testing method, as discussed in Chapter 5,6, and 7 accordingly. These validation methods were carried out to ensure that the proposed design principles are useful and reliable for future researchers when designing the MSL mobile applications for HI learners, particularly the alpha generations.

In general, sixteen design principles that have been proposed have been well-accepted by the experts through expert review activities that have been carried out. Then, a semi-working prototype was successfully designed and developed based on the proposed design principles through the prototyping approach. The findings in the user experience testing through one pilot test and two direct observation sessions indicate that the proposed design principles for the MSL mobile application for HI alpha generations successfully fulfill the needs of the HI alpha generations. Thus, it can be concluded that the proposed design

principles of the MSL mobile application are significantly useful in designing and developing the MSL mobile application for HI learners, including the alpha generations.

8.4 Research Objectives: Revisit

Having completed the two supporting objectives, the main aims have been achieved towards the end of this study. The first objectives were achieved through content analysis and comparative analysis, and extensive studies have been made. Then, sixteen design principles were successfully identified through the UCD approach and the involvement of the experts and users' representatives. Then, the second objective was achieved through the validation methods carried out. Expert review (Chapter 5), prototyping (Chapter 6), and user experience testing (Chapter 7) approaches were chosen to validate the proposed design principles to ensure their usefulness and reliability.

The experts reveal that the proposed design principles are valid to be prototyped through expert review activities. Then, the MSL mobile application prototype was designed and developed based on sixteen proposed design principles. Finally, the proposed design principles were validated through user experience testing involving six HI alpha generations as the main subjects. The semi-working prototype was used as the main instrument. The subjects' response through two direct observation sessions indicates that the proposed design principles are useful and valid for future researchers to refer to in the future development of the MSL mobile application for HI alpha generations.

8.5 Implications of Study to Theory and Practical

The implication of this study can be seen in two aspects which are the body of knowledge and theory and practical.

In terms of the body of knowledge, this study proposed an extension of the NMDG by considering the contexts of the HI alpha generations. Although the existing NMDG has been extended by Kumar (2019) that considers the contexts of mobile applications, it does not cater to the needs of the HI alpha generations. Besides, this study interprets that the proposed design principles for the MSL mobile application for the HI alpha generations that are constructed based on the previous concepts and theories as well as supported with the UCD approach, are essential to make it useful and reliable for the future researchers to refer in designing and developing the MSL mobile applications for the HI learners, as proven in this study.

Additionally, the design principles and prototype are tangible artefacts that could be beneficial in the form of content selling. People who have ideas and knowledge in developing mobile applications for HI learners, particularly the alpha generations, but lack technical skills on the technique to market their knowledge could sell this knowledge depending on their initiatives. This could enrich the sources of learning materials in the market, especially for the HI community.

8.6 Limitations and Recommendations for Future Works

This study highlights two areas of limitations which are (i) the construction of the design principles for the MSL mobile application and (ii) the validation of the proposed design principles. The following subsections briefly discuss each of the limitations in detail.

8.6.1 Design Principles for the MSL Mobile Application

In constructing the design principles for the MSL mobile applications for the HI alpha generations based on the NMDG, various methods were implemented throughout this study which are comparative analysis, content analysis, elicitation works, and the UCD approach. The content and comparative analysis made on the existing models of the MSL mobile applications are less exhaustive since the models are in the form of prototype screenshots and figures.

Then, the UCD approach was utilized to identify and confirm the proposed design principles for the MSL mobile applications for the HI alpha generations based on the NMDG. However, this study involves the users' representations in the UCD approach instead of the actual users due to the limitations of the actual users who are children with hearing impairment. Although it complies with the rich input, it still does not consider the opinion of the actual users. Future researchers could involve the actual users in future works that will provide different results.

Additionally, the design principles are a type of generic model which could be utilized as a reference to develop the MSL mobile application for any school subjects that the users prefer. Future researchers could propose a new set of design principles focusing on subjects such as Mathematics and music, which might contain more specific elements and principles.

8.6.2 Validation of the Proposed Design Principles

As was previously said, the proposed design concepts were validated using three different methods which are expert review, prototyping, and user experience testing. Although the suggested design concepts have been validated effectively, the feedback can yet be improved.

In this study, the experts were selected from academic and practitioner backgrounds, as suggested by previous researchers, as mentioned in Chapter 5, to validate the proposed design principles. Although it complies with rich input, the opinions provided by the industry experts are therefore insufficient. The discoveries from industrial specialists or the creators of mobile applications for the impaired, particularly the HI alpha generations, may be improved by future researchers. Additionally, future researchers could consider involving academicians from overseas to get better viewpoints from them to enhance this study.

As for the prototyping method, although the prototype has been successfully designed and developed to translate the proposed design principles, the prototype was designed using free online software with limited access. Thus, in the future, the researchers could enhance the prototype using the full access software to design the prototype better. So, it could attract more attention from the users and improve the design principles through users' feedback.

8.7 Chapter Summary

This study has conducted an exhaustive and systematic investigation in proposing the design principles for the MSL mobile application for the HI alpha generations based on the NMDG. All relevant components in constructing the design principles were considered and validated through three validation approaches which are expert review, prototyping, and user experience testing. From the findings obtained, there were indications that the proposed design principles have several advantages that could be highlighted as follows:

i. The proposed design principles for the MSL mobile application are useful in guiding future researchers or developers in designing and developing the MSL mobile applications for HI learners, particularly the alpha generations.

ii. The MSL mobile application is useful in evoking the cognitive ability among the HI alpha generations.

iii. The MSL mobile application is useful in supporting the HI alpha generations to learn sign language independently through the prototype.

iv. The MSL mobile application is useful in supporting the HI alpha generations to learn sign language interactively.

The HI alpha generations must benefit from a learning material that deems a relevant theoretical framework in its design and development. The learning materials should assist the learners in learning independently without facing difficulties as they deserve a brighter future than normal learners.

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APPENDICES

Appendix A: Research Operational Template (ROT)

Research Operational Template (ROT)

ERMIERA SHAFIKA BINTI MOKHTAR (827717)

SUPERVISOR: DR AZIZAH BINTI CHE OMAR

CO-SUPERVISOR: TS. DR. NURULNADWAN BINTI AZIZ

WORKING TITLE:

FORMATION OF DESIGN PRINCIPLES OF MALAY SIGN LANGUAGE (MSL) MOBILE APPLICATION FOR HEARING-IMPAIRED ALPHA GENERATION BASED ON NIELSEN'S AND MOLICH'S DESIGN GUIDELINES

a) BRIEF OVERVIEW OF THE STUDY

In Malaysia, hearing-impaired (HI) learners including the alpha generation (children with hearing impairment that were born after 2010) utilize the Malay Sign Language (MSL) as a medium to support them in communication and learning at school (Priya Kulasagaran, 2014). MSL is widely used in Malaysia to ensure that all HI learners use the same types of sign language to avoid miscommunication among them and society. To get proper and standard education on MSL, the HI learners are required to register into special schools. In Addition, there are various types of MSL mobile application such as MyBIM have been developed and currently available in the market to support HI learners in learning sign language. However, according to Aziz (2020), the present MSL mobile applications fail to hybridize Nielsen's and Molich's Design Guidelines (NMDG) in their study which is critical for evoking cognitive ability among HI learners. On the other hand, the NMDG has been reformed by Kumar (2019) as the existing NMDG are too generic and not suitable to evaluate the mobile applications. However, the NMDG that has been reformed does not consider the HI learners' context in evaluating the mobile application. Furthermore, most of the existing MSL mobile applications fail to satisfy the HI learners' needs in terms of multimedia elements used and user interface as well as limitation of functionalities. Due to that, the existing MSL mobile applications fail to support HI learners' learning activities. Thus, this study aims to propose a MSL mobile application that hybridizing NMDG to enhance their understanding of learning sign language. Besides, a new set of design guidelines that consider the HI learners will be developed throughout this study. Then, a working prototype of MSL mobile application will be developed throughout this study by considering the needs of HI learners in terms of multimedia elements, user interface and functionalities. This study will benefit the instructional designers and other researchers as this research will provide complete heuristics design guidelines to make learning materials and mobile application for HI alpha generation, particularly in sign language learning.

b) PROBLEM STATEMENT

- **Current Issues**
  - Existing MSL mobile applications fail to hybridize NMDG within their study as it is important to evoke cognitive ability among HI learners especially HI alpha generation (Aziz,2020).
  - Existing NMDG are too generic and does not consider HI learners' context (Kumar,2019).

- Existing MSL mobile applications fail to satisfy HI learners' needs due to unattractive user interface, lacks multimedia elements and limitation of functionalities (Expert 1, personal communication, November 11, 2020).

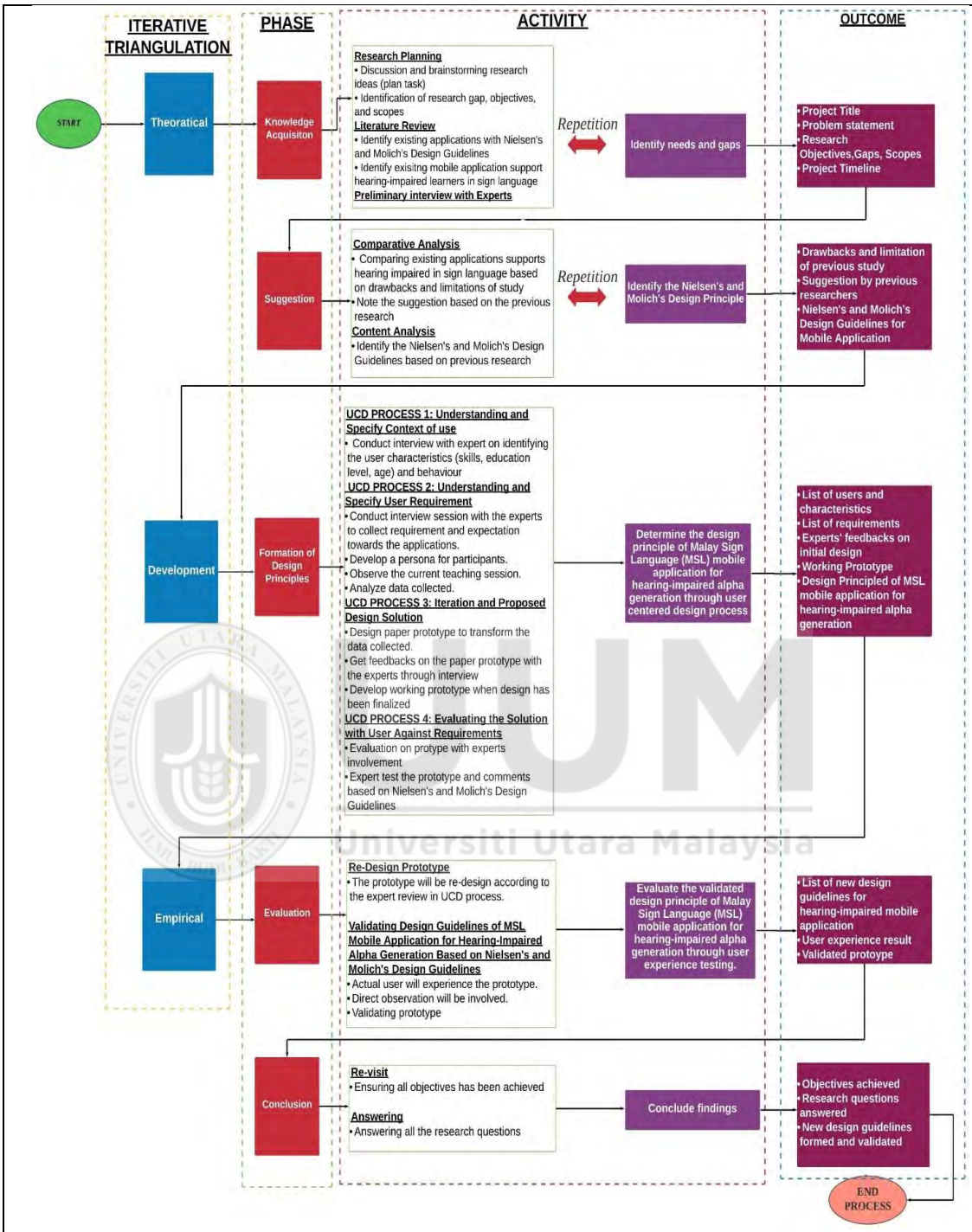
- **Specific Gaps**
  - None of existing MSL mobile applications have been hybridizing NMDG within their study (Aziz,2020).
  - Existing NMDG for mobile applications are too generic and does not consider HI alpha generation in their study (Kumar, 2019).
  - Existing MSL mobile application need to be enhance in terms of multimedia elements and functionalities that suitable for HI alpha generation context functionalities (Expert 1, personal communication, November 11, 2020).
- **Proposed Solution – (NOVELTY)**
  - Formation of the Design Principles of MSL Mobile Application for Hearing Impaired Alpha Generation Based on Nielsen's and Molich's Design Guidelines.

c) OBJECTIVES

a) To determine the design principles of MSL mobile application for HI alpha generation through a user-centered design (UCD) process.

b) To validate the design principles of MSL mobile application for HI alpha generation through prototyping, expert review, and user-experience testing.

c) RESEARCH AND THEORETICAL FRAMEWORK



d) SIGNIFICANCE OF RESEARCH

- **Design Principles of MSL Mobile Application**
  - Extension of NMDG will be formed by considering the HI alpha generation context.
  - Other researchers in developing a mobile application for HI alpha generation supported by these guidelines.
  - Instructional designers will get benefits from this design principles as it provides complete heuristics design guidelines to make learning materials and mobile application for HI alpha generation, particularly in sign language learning.

- **Working Prototype of MSL Mobile Application**
  - The prototype will give an initial view of the MSL mobile application to the actual users and experts as they will be involved in the design process.
  - HI teachers will get benefits from this working prototype as they can ensure that the learning contents follow the quality and standard of MSL before the application being launched.

- **Empirical Findings**
  - The prototype will be evaluated by the experts based on NMDG to validate the design principles that will be formed.
  - A validated and reliable design principles for MSL mobile application for HI alpha generation will be identified.

e) RESEARCH QUESTIONS	**f) METHODS**	**g) DATA ANALYSIS**
1. How to determine the design principles of the MSL mobile application for HI alpha generation?	• User Centered Design • Content Analysis • Comparative Analysis	• Thematic Analysis
2. How to validate the design principles of the MSL mobile application for HI alpha generation?	• Prototyping • Expert Review • User Experience	• Thematic Analysis • Evaluation Result Analysis

h) RESEARCH DESIGN	**i) SAMPLING TECHNIQUE**
• Qualitative approach • Iterative Triangulation Method (ITM) • Design science research method (DSRM)	**Sampling Technique:** Convenience Sampling**.** **Population:** Hearing-Impaired Children and Teachers in Special Education School Sungai Petani, Kedah, Malaysia.

j) EXPECTED MAIN FINDINGS

Design Principles for MSL Mobile Application for HI Alpha Generation Based on Nielsen's and Molich's Design Guidelines.

k) CONTRIUBUTION TO THE BODY OF KNOWLEDGE (THEORY, METHODOLOGY, PRACTICALITY)

- **THEORY -** Extension of NMDG for mobile application that considering HI alpha generation.
- **METHODOLOGY** - Steps in determining the design principles of the MSL mobile application for HI alpha generation based on methodology adopted from previous study by Dermawi (2018).
- **PRACTICALITY** - Develop new MSL mobile application for HI alpha generation that hybridize NMDG.

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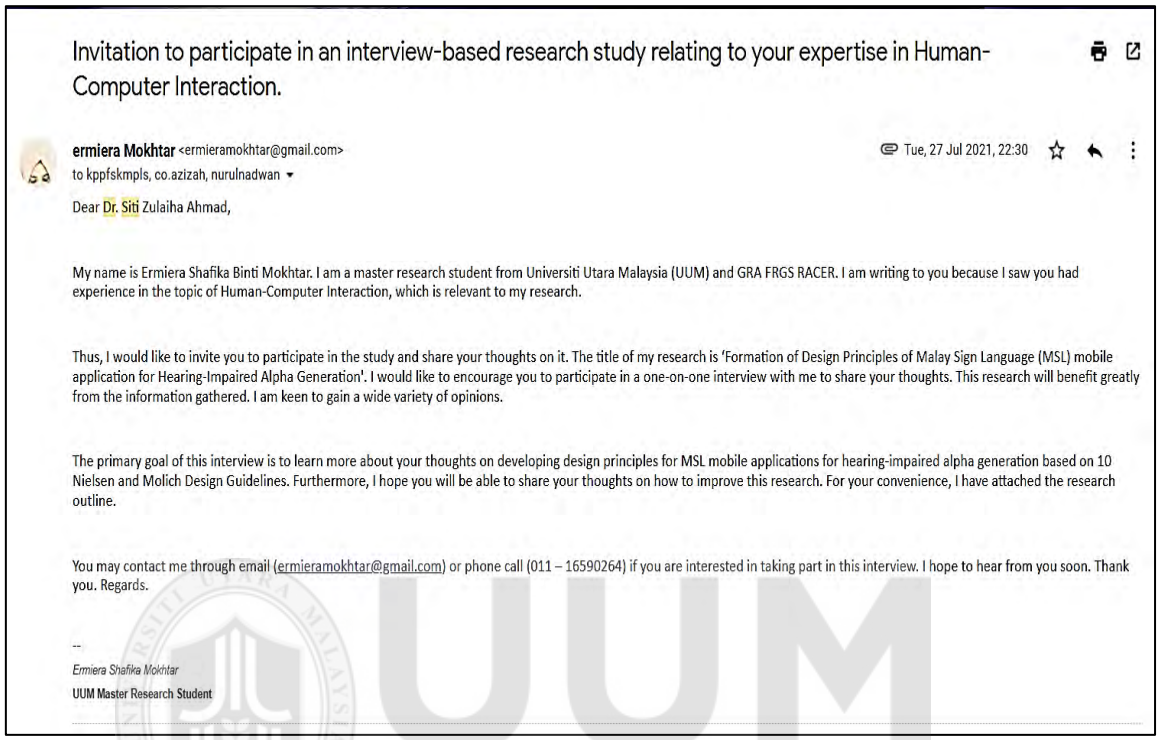
Appendix B: Lists of NMDG by Kumar (2019)

Heuristics	Evaluation
Visibility of the system status	providing appropriate feedback when user is accessing a mobile learning application
Match between the system and real world	Easily recognized the use of text and enable the users to identify the elements on the apps quickly
User control and Freedom	use of text and icons which are intuitive and easily recognizable which enables users to quickly identify and comprehend elements on the app
Consistency and Standards	allow individuals to go to different menus with ease and ability to quickly exit and enter different selections of the application
Error Preventions	mobile learning application having consistent and similar features to any other mobile learning application
Recognition Rather than Recall	users can complete tasks in a mobile learning application with minimum or no errors and quickly recover from errors
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
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
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.
Help and Documentation	assist users in finding specific content, assist in learning the application, provide help and guidance in identifying element in the app, provide examples to perform tasks, and assist in the completion of crucial tasks.
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
Content organization	the content needs to highlight key learning objectives, some elements of content organization are content would need to be optimized to fit in one screen, multiple screens can be used to display content if content is large
Visual representation	use of pictures, icons, screen objects, sound, text color, background color and animations to help user learning process

Appendix C: Sample of Email Invitation for Experts



Invitation to participate in an interview-based research study relating to your expertise in Human-Computer Interaction.

ermiera Mokhtar <ermieramokhtar@gmail.com> Tue, 27 Jul 2021, 22:30

to kppfskmpls, co.azizah, nurulnadwan

Dear Dr. Siti Zulaiha Ahmad,

My name is Ermiera Shafika Binti Mokhtar. I am a master research student from Universiti Utara Malaysia (UUM) and GRA FRGS RACER. I am writing to you because I saw you had experience in the topic of Human-Computer Interaction, which is relevant to my research.

Thus, I would like to invite you to participate in the study and share your thoughts on it. The title of my research is 'Formation of Design Principles of Malay Sign Language (MSL) mobile application for Hearing-Impaired Alpha Generation'. I would like to encourage you to participate in a one-on-one interview with me to share your thoughts. This research will benefit greatly from the information gathered. I am keen to gain a wide variety of opinions.

The primary goal of this interview is to learn more about your thoughts on developing design principles for MSL mobile applications for hearing-impaired alpha generation based on 10 Nielsen and Molich Design Guidelines. Furthermore, I hope you will be able to share your thoughts on how to improve this research. For your convenience, I have attached the research outline.

You may contact me through email (ermieramokhtar@gmail.com) or phone call (011 – 16590264) if you are interested in taking part in this interview. I hope to hear from you soon. Thank you. Regards.

--

Ermiera Shafika Mokhtar

UUM Master Research Student

Appendix D: Sample of Dean's Appointment Letter for Experts

PUSAT PENGAJIAN TEKNOLOGI MULTIMEDIA DAN KOMUNIKASI
SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION
Universiti Utara Malaysia
06010 UUM SINTOK
KEDAH DARUL AMAN
MALAYSIA

Tel: 604-928 5801
Faks (Fax): 604-928 5804
Laman Web (Web):http://www.smmtc.uum.edu.my

Tarikh: 24 Ogos 2021

Ts. Dr. Siti Zulaiha Ahmad
Ketua Pusat Pengajian Sains Komputer
Fakulti Sains Komputer dan Matematik,
Universiti Teknologi MARA (UiTM) Cawangan Perlis (Kampus Arau)
02600 Arau, Perlis, Malaysia.

Dr,

PERLANTIKAN SEBAGAI PAKAR PENILAI PENGESAHAN DAPATAN KAJIAN

Dengan segala hormatnya perkara di atas adalah dirujuk.

2. Sukacita dimaklumkan bahawa Ermiera Shafika Mokhtar (827717) merupakan pelajar sarjana di bawah penyeliaan saya dan sedang menyiapkan kajian bertajuk *"Formation of Design Principles of Malay Sign Language (MSL) Mobile Applications for Hearing-Impaired Alpha Generation"*.

3. Sehubungan itu, pihak Dr. telah dilantik sebagai panel pakar rujuk dan penyemak dapatan kajian yang akan digunakan dalam kajian ini. Adalah diharapkan pihak Dr. dapat menyemak dan mengesahkan dapatan kajian sepanjang kajian ini dijalankan.

4. Bersama ini disertakan maklumat ringkas berkaitan kajian untuk semakan Dr. Sekiranya terdapat sebarang kemusykilan, boleh menghubungi Ermiera Shafika Mokhtar di talian 011 – 1659 0264 atau melalui alamat emel ermieramokhtar@gmail.com.

5. Kerjasama Dr. bagi menjayakan kajian ini amat saya hargai dan saya dahulukan dengan ucapan terima kasih.

Sekian, terima kasih.

"KEDAH SEJAHTERA – NIKMAT UNTUK SEMUA"
"ILMU BUDI BAKTI"

Saya yang menjalankan amanah

Dr. Azizah Che Omar
Ketua Penyelidik Geran RACER
Pusat Pengajian Teknologi Multimedia dan Komunikasi
Universiti Utara Malaysia

Appendix E: Sample of Checklist for Experts

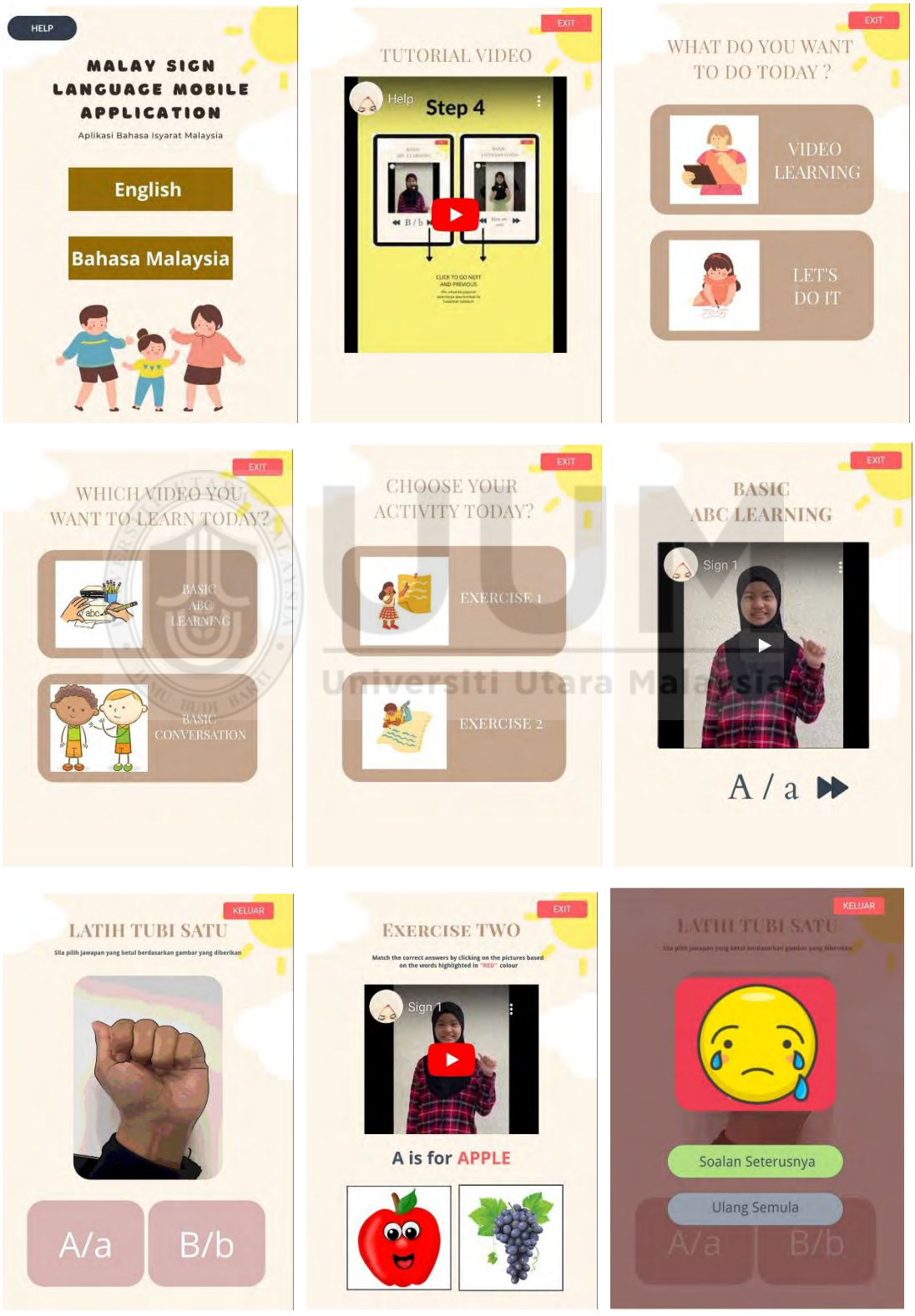
No	Proposed Design Principles for Malay Sign Language Mobile Application for Hearing-Impaired Alpha Generation	Description	Agree	Disagree	Comments And Feedback
Usability Heuristics for Mobile Application (1): Visibility of the system status					
1	Ensure all the screens provide instructions to notify the user's earners of their current states.	All the screens should be provided with instructions so that the users know their current states.			
Usability Heuristics for Mobile Application (2): Match between system and real world					
2	Matching the sign language learning content with the local education standard	The sign language learning content should be similar to the local education standard to ensure it is standardized and avoid misunderstanding.			
Usability Heuristics for Mobile Application (3): User Control and Freedom					
3	The applications should enable the HI learners to leave the application anytime.	The users should be allowed to leave the applications with a single click.			
Usability Heuristics for Mobile Application (4): Consistency and Standard					
4	The sign language video learning content must be coherent with the exercises provided	The exercises must be consistent with the video learning to measure the cognitive ability of the mobile applications.			
5	Use standard fonts and sizes for the texts.	As for sign language learning, content should follow the standard font, such as Calibri. Besides, the size of the font should be consistent for all screens.			
6	The sizes and quality of images or graphics should be maximized and consistent.	The quality of images, graphics, and videos should be maximized to attract the users' attention as they are attracted more to the visuals.			

Usability Heuristics for Mobile Application (5): Error Prevention					
7	The sign language application feedback should be designed with pop-out dialogue to catch users' attention.	Every action made by the users should be associated with the feedback through pop-out dialogue to avoid being lost in the application. For example, an alert should be provided every time they answer the questions to notify them whether their answers are right or wrong.			
Usability Heuristics for Mobile Application (6): Recognition Rather than Recall					
8	The button design should be clickable and consistent according to the functionalities.	The buttons or menus should be consistent, and the colors should follow the standards.			
9	Use the recognizable characters in the application design	It is advisable to use the cartoon character recognizable by the users because they easily remember what they are familiar with.			
Usability Heuristics for Mobile Application (7): Flexibility and Efficiency of Use					
10	Ensure flexibility of navigation for the users in using the application	The users should have flexibility while utilizing an application to avoid feeling distracted and pressured. For example, HI learners can skip the questions that they do not want to answer to the following questions.			
Usability Heuristics for Mobile Application (8): Aesthetic and Minimalist Design					
11	Minimize the cognitive load by minimizing the interface design.	The interface design should be simple and less crowded. According to usability experts, having only 5-7 elements within a screen is good for enhancing cognitive ability.			
12	The interface's color should be minimal but attractive with a good color combination.	Using attractive colors but less crowded to attract their attention and interest is advisable.			
Usability Heuristics for Mobile Application (9): Help Users Recognize and Recover from Errors					
13	The application should be associated with undo and redo button for the HI learners to recover from mistakes.	A sign language application should provide 'Redo' and 'Undo' buttons to help users have a smooth experience using the applications. The users tend to make massive mistakes while using the applications.			

Usability Heuristics for Mobile Application (10): Help and Documentation					
14	Assist the users in using the application by providing a manual with a video tutorial	The users rely on video and assistance from their parents to help them learn. Hence, a video tutorial is needed to explain how the applications work to the parents and HI learners.			
Usability Heuristics for Mobile Application (11): Selection Driven Commands					
15	Maximized the usage of a button as well as click-and-play functions	Optimizing the usage of buttons and providing click-play functions is advisable to avoid making massive mistakes when interacting with the applications. The use buttons should be fully utilized.			
Usability Heuristics for Mobile Application (12): Visual Representation					
16	Use more multimedia elements than text and static images as the HI learners rely more on graphics than texts.	Images and pictures can enhance memorability as they rely heavily on visuals rather than plain texts.			

Appendix F: Sample of Initial Prototype Design

Appendix G: Sample of Initial Semi-Working Prototype



Appendix H: Sample of ERAS Approval Letter

KEMENTERIAN PENDIDIKAN MALAYSIA
BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
ARAS 1-4, BLOK E8
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA

TEL : 0388846591
FAKS : 0388846579

Ruj. Kami : KPM.600-3/2/3-eras(11768)
Tarikh : 19 Januari 2022

ERMIERA SHAFIKA BINTI MOKHTAR
NO. KP : 970715085288

NO 169, JALAN SM2A/10,
TAMAN FASA 2A, 32040 SERI MANJUNG
PERAK

Tuan,

KELULUSAN BERSYARAT UNTUK MENJALANKAN KAJIAN :
FORMATION OF DESIGN PRINCIPLES OF MALAY SIGN LANGUAGE (MSL) MOBILE APPLICATION FOR HEARING-IMPAIRED ALPHA GENERATION

Perkara di atas adalah dirujuk.

2. Sukacita dimaklumkan bahawa permohonan tuan untuk menjalankan kajian seperti di bawah telah diluluskan dengan syarat :

" KELULUSAN INI BERGANTUNG KEPADA PERTIMBANGAN PENGARAH BAHAGIAN PENDIDIKAN KHAS. "

3. Kelulusan adalah berdasarkan kepada kertas cadangan penyelidikan dan instrumen kajian yang dikemukakan oleh tuan kepada bahagian ini. Walau bagaimanapun kelulusan ini bergantung kepada kebenaran Jabatan Pendidikan Negeri dan Pengetua / Guru Besar yang berkenaan.

4. Surat kelulusan ini sah digunakan bermula dari **1 Februari 2022** hingga **28 Ogos 2022**

5. Tuan dikehendaki menyerahkan senaskhah laporan akhir kajian dalam bentuk *hardcopy* bersama salinan *softcopy* berformat pdf dalam CD kepada Bahagian ini.Tuan juga diingatkan supaya mendapat kebenaran terlebih dahulu daripada Bahagian ini sekiranya sebahagian atau sepenuhnya dapatan kajian tersebut hendak diterbitkan di mana-mana forum, seminar atau diumumkan kepada media massa.

Sekian untuk makluman dan tindakan tuan selanjutnya. Terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah,

Ketua Penolong Pengarah Kanan
Sektor Penyelidikan dan Penilaian Dasar
b.p. Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pendidikan Malaysia

salinan kepada:-

BAHAGIAN PENDIDIKAN KHAS
JABATAN PENDIDIKAN KEDAH
JABATAN PENDIDIKAN PERAK
JABATAN PENDIDIKAN PERLIS

* SURAT INI DIJANA OLEH KOMPUTER DAN TIADA TANDATANGAN DIPERLUKAN *

Appendix I: Sample of Approval Letter from Jabatan Pendidikan Khas Malaysia

KEMENTERIAN PENDIDIKAN MALAYSIA
BAHAGIAN PENDIDIKAN KHAS
ARAS 2, BLOK E2,
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA

Tel : 03-8884 9190
Faks: 03-8888 6670
Laman Web://www.moe.gov.my

Ruj. Kami : KPM.600-2/1/4 Jld.5 (91)
Tarikh : 22 Februari 2022

Ermiera Shafika binti Mokhtar
No 169, Jalan SM2A/10
Taman Fasa 2A
32040 Seri Manjung
PERAK

Puan,

MEMOHON KEBENARAN MENJALANKAN KAJIAN BERSAMA KANAK-KANAK PEKAK

Dengan hormatnya perkara di atas dan surat daripada Bahagian Perancangan dan Penyelidikan Pendidikan [Rujukan: KPM.600-3/2/3-eras(11768)] bertarikh 19 Januari 2022 dirujuk.

2. Sukacita dimaklumkan bahawa Bahagian Pendidikan Khas (BPKhas), Kementerian Pendidikan Malaysia (KPM) tiada halangan untuk membenarkan puan menjalankan kajian bertajuk **"Formation of Design Principles of Malay Sign Language (MSL) Mobile Application for Hearing-Impaired Alpha Generation."**

3. Walau bagaimanapun, BPKhas, KPM ingin mengingatkan puan bahawa:

3.1. Kelulusan ini tertakluk kepada klausa 5.1.16 Garis Panduan Pengurusan dan Pengoperasian Sekolah 3.0 yang menyatakan bahawa:

*"Pihak luar yang bukan warga KPM termasuk orang kenamaan **tidak dibenarkan** memasuki kawasan sekolah kecuali bagi tujuan pembaikan dan penyelenggaraan sekolah dengan syarat telah divaksin lengkap."*

...2/-

Appendix J: Sample of Notification Letter for Principal

PUSAT PENGAJIAN TEKNOLOGI MULTIMEDIA DAN KOMUNIKASI
SCHOOL OF MULTIMEDIA TECHNOLOGY AND COMMUNICATION
Universiti Utara Malaysia
06010 UUM SINTOK
KEDAH DARUL AMAN
MALAYSIA

Tel: 604 - 928 5801
Faks (Fax): 604 - 928 5804
Laman Web (Web):http://www.smmtc.uum.edu.my

Tarikh: 8 Februari 2022

Guru Besar,
Sekolah Kebangsaan Pendidikan Khas Sungai petani,
Mukim bujang,
08400, Merbok, Kedah
Malaysia.

Ybhg Tuan/Puan,

PERMOHONAN UNTUK MENJALANKAN KAJIAN PENYELIDIKAN BERTAJUK "*DESIGN MODEL FOR SIGN LANGUAGE IN DIGITAL SOCIETY 5.0: HYBRIDIZING NIELSEN AND MOLICH'S DESIGN GUIDELINES*" TAJAAN GERAN RACER DENGAN NO RUJUKAN RACER/1/2019/ICT01/UUM//3

Dengan segala hormatnya perkara di atas adalah dirujuk.

2. Dimaklumkan bahawa saya sebagai Ketua Penyelidik bagi geran di atas ingin memohon keizinan dan kelulusan Ybhg. Tuan/Puan untuk menjalankan kajian yang melibatkan guru-guru pendidikan khas dan murid-murid berpendengaran terhad di Sekolah Pendidikan Khas Sungai Petani, Kedah sebagai reponden kajian.

3. Ahli-ahli penyelidik lain yang akan turut serta ialah Dr. Nurulnadwan Aziz, dan GRA Emiera Shafika Binti Mokhtar Matrik No (827717). Dilampirkan juga surat kebenaran penyelidikan dari Kementerian Pendidikan Malaysia Bahagian Penerangan dan Penyelidikan Dasar Pendidikan untuk rujukan pihak Ybhg. Tuan/Puan.

4. Saya berharap Ybhg. Tuan/Puan dapat memberi keizinan dan kelulusan terhadap permohonan kumpulan penyelidikan kami bagi menjayakan objektif penyelidikan yang telah ditetapkan. Perhatian dan kerjasama daripada Ybhg. Tuan/Puan amatlah dihargai dan diucapkan terima kasih.

Sekian, terima kasih.

Appendix K: Sample of Consent Forms

Intan Sampel - 1A

LAMPIRAN P

Borang Keizinan bagi Penerbitan Bahan yang berkaitan dengan Peserta Kajian (Halaman Tandatangan)

Tajuk Kajian: **Formation of Design Principles of Malay Sign Language (MSL) Mobile Application for Hearing-Impaired Alpha Generation**

Nama Penyelidik: **Ermiera Shafika Binti Mokhtar**

Untuk menyertai kajian ini, anda atau wakil sah anda mesti menandatangani mukasurat ini.
Dengan menandatangani mukasurat ini, saya memahami yang berikut:

- Bahan yang akan diterbitkan tanpa dilampirkan dengan nama saya dan setiap percubaan yang akan dibuat untuk memastikan ketanpanamaan saya. Saya memahami, walaubagaimanapun, ketanpanamaan yang sempurna tidak dapat dijamin. Kemungkinan sesiapa yang menjaga saya di hospital atau saudara dapat mengenali saya.
- Bahan yang akan diterbitkan dalam penerbitan mingguan/bulanan/dwibulanan/suku tahunan/dwi tahunan merupakan satu penyebaran yang luas dan tersebar ke seluruh dunia. Kebanyakan penerbitan ini akan tersebar kepada doktor-doktor dan juga bukan doktor termasuk ahli sains dan ahli jurnal.
- Bahan tersebut juga akan dilampirkan pada laman web jurnal di seluruh dunia. Sesetengah laman web ini bebas dikunjungi oleh semua orang.
- Bahan tersebut juga akan digunakan sebagai penerbitan tempatan dan disampaikan oleh ramai doktor dan ahli sains di seluruh dunia.
- Bahan tersebut juga akan digunakan sebagai penerbitan buku oleh penerbit jurnal.
- Bahan tersebut tidak akan digunakan untuk pengiklanan ataupun bahan untuk membungkus.

Saya juga memberi keizinan bahawa bahan tersebut boleh digunakan sebagai penerbitan lain yang diminta oleh penerbit dengan kriteria berikut:

- Bahan tersebut tidak akan digunakan untuk pengiklanan atau bahan untuk membungkus.
- Bahan tersebut tidak akan digunakan di luar konteks – contohnya: Gambar tidak akan digunakan untuk menggambarkan sesuatu artikel yang tidak berkaitan dengan subjek dalam foto tersebut.

INTAN SUDAYA MOHD KHAIRUL NIZAR

Nama Peserta

131106-02-0924 — No. MyKID Peserta

T/tangan Peserta/Ibu Bapa /Penjaga

23/01/2022 — Tarikh (dd/mm/yy)

ERMIERA SHAFIKA BT MOKHTAR — Nama & Tandatangan Individu yang Mengendalikan Perbincangan Keizinan

23/01/22 — Tarikh (dd/MM/yy)

Nota: i) Semua peserta yang mengambil bahagian dalam projek penyelidikan ini tidak dilindungi insuran.

LAMPIRAN S

Borang Keizinan Peserta
(Halaman Tandatangan)

Tajuk Kajian: **Formation of Design Principles of Malay Sign Language (MSL) Mobile Application for Hearing-Impaired Alpha Generation**

Nama Penyelidik: **Ermiera Shafika Binti Mokhtar**

Untuk menyertai kajian ini, anda atau wakil sah anda mesti menandatangani mukasurat ini. Dengan menandatangani mukasurat ini, saya mengesahkan yang berikut:

- Saya telah membaca semua maklumat dalam Borang Maklumat dan Keizinan Peserta/Pelajar ini **termasuk apa-apa maklumat berkaitan risiko yang ada dalam kajian** dan saya telah pun diberi masa yang mencukupi untuk mempertimbangkan maklumat tersebut.
- Semua soalan-soalan saya telah dijawab dengan memuaskan.
- Saya, secara sukarela, bersetuju menyertai kajian penyelidikan ini, mematuhi segala prosedur kajian dan kakitangan lain yang berkaitan apabila diminta.
- Saya boleh menamatkan penyertaan saya dalam kajian ini pada bila-bila masa.
- Saya telah pun menerima satu salinan Borang Maklumat dan Keizinan Peserta untuk simpanan peribadi saya.

INTAN SURAYA MOHD KHAIRUL NIZAR
Nama Peserta

131106-02-0924
No. Kad Pengenalan/MyKid Peserta

Tandatangan Peserta atau Ibu Bapa/Penjaga

23/01/2022
Tarikh (dd/MM/yy)
(Masa jika perlu)

ROMIEEP SHAFIKA BT MOKHTAR
Nama & Tandatangan Individu yang Mengendalikan Perbincangan Keizinan

23/01/2022
Tarikh (dd/MM/yy)

SITI NORSHAHILA MOHAMAD KHIR
Nama Saksi dan Tandatangan

23/1/2022
Tarikh (dd/MM/yy)

Nota: Semua peserta yang mengambil bahagian dalam projek penyelidikan ini tidak dilindungi insuran.

MAKLUMAT KAJIAN

Tajuk Kajian:	Formation of Design Principles of Malay Sign Language (MSL) Mobile Application for Hearing-Impaired Alpha Generation Based on Nielsen's and Molich's Design Guidelines.
Nama Penyelidik dan Penyelidik Bersama:	1. Ermiera Shafika Binti Mokhtar (827717) 2. Dr. Azizah Binti Che Omar 3. Ts. Dr. Nurulnadwan Binti Aziz

PENGENALAN

Anak anda **Intan Suraya** adalah dipelawa untuk menyertai satu kajian penyelidikann kajian intervensi secara sukarela. Kajian ini adalah berkaitan pengenalan aplikasi pembelajaran Bahasa Isyarat Malaysia (BIM) kepada para pelajar yang menghadapi masalah pendengaran dan menggunakan BIM sebagai bahasa pengantaraan dalam berkomunikasi.

Adalah penting bagi anda membaca dan memahami maklumat kajian sebelum anda bersetuju untuk menyertai kajian penyelidikan ini. Sekiranya anda menyertai kajian ini, anda akan menerima satu salinan borang ini untuk simpanan anda.

Penyertaan anak anda di dalam kajian ini dijangka mengambil masa selama 30 minit bagi satu sesi pengenalan aplikasi pembelajaran kepada anak anda. Seramai 6 orang pelajar dijangka akan menyertai kajian ini.

TUJUAN KAJIAN

Kajian ini bertujuan untuk menentukan prinsip rekaan bagi membina aplikasi pembelajaran Bahasa Isyarat Malaysia (BIM) untuk pelajar yang menghadapi masalah pendengaran. Selain itu, tujuan kajian ini adalah untuk mengesahkan prinsip rekaan yang telah diperoleh melalui kajian ini.

KELAYAKAN PENYERTAAN

Salah seorang kakitangan kajian akan membincangkan kelayakan untuk menyertai kajian ini. Adalah penting anda berterus terang kakitangan tersebut.

Kajian ini akan melibatkan individu yang mempunyai masalah pendengaran dan lahir pada tahun 2010 dan ke atas. Selain itu, ia akan melibatkan pelajar yang mendaftar dengan Sekolah/Institusi Pendidikan Khas yang didaftkan di bawah Kementerian Pelajaran Malaysia.

Kajian ini tidak akan melibat individu yang mempunyai masalah kesihatan selain dari masalah pendegaran dan lahir kurang dari tahun 2010 serta yang tidak berdaftar.

PROSEDUR-PROSEDUR KAJIAN

1. Para peserta/pelajar akan dibawa masuk ke dalam makmal komputer bersama guru.
2. Para peserta/pelajar akan diberi keterangan secara terperinci bagi menggunakan aplikasi ini.
3. Para peserta/pelajar akan diberikan masa selama 30 minit untuk menggunakan aplikasi ini dan lingkah laku mereka akan dirakamkan.
4. Setelah tamat, para peserta/pelajar akan ditemu ramah untuk bertanyakan tentang pengalaman dan pendapat mereka tentang aplikasi berikut.

RISIKO

Kajian ini berisiko untuk menggangu emosi anak anda semasa penggunaan aplikasi ini namun, kami akan menyediakan guru yang berpengalaman untuk bersama-sama membantu anak anda untuk menggunakan aplikasi ini.

Sila maklumkan kepada kakitangan kajian sekiranya anda menghadapi sebarang masalah atau mempunyai sebarang maklumat penting yang mungkin mengubah persetujuan anda untuk terus menyertai kajian ini.

PENYERTAAN DALAM KAJIAN

Penyertaan anak anda dalam kajian ini adalah secara sukarela. Anda berhak menolak untuk menyertai kajian ini atau menamatkan penyertaan anda pada bila-bila masa, tanpa sebarang kehilangan manfaat yang sepatutnya anda perolehi.

Penyertaan anda juga mungkin boleh diberhentikan oleh kakitangan kajian ini tanpa persetujuan anda sekiranya anda didapati tidak sesuai untuk meneruskan kajian ini berdasarkan protokol kajian. Kakitangan kajian akan memaklumkan anda sekiranya anda perlu diberhentikan dari menyertai kajian ini.

MANFAAT YANG MUNGKIN

Prosedur kajian ini akan diberikan kepada anda tanpa kos. Anda boleh menerima maklumat tentang penggunaan aplikasi Bahasa Isyarat Malaysia (BIM) serta mengakses modul secara percuma.

Hasil kajian ini diharapkan dapat memberi manfaat kepada masyarakat umum untuk mempunyai akses pada bila-bila masa untuk mempelajari Bahasa Isyarat Malaysia.

Anda tidak akan menerima sebarang pampasan kerana menyertai kajian ini. Namun sebarang keperluan perjalanan berkaitan dengan penyertaan ini akan diberikan.

PERSOALAN

Sekiranya anda mempunyai sebarang soalan mengenai prosedur kajian ini atau hak-hak anda, sila hubungi;

Ermiera Shafika Binti Mokhtar

Fakulti Teknologi Multimedia dan Komunikasi

Awang Had Salleh,

Universiti Utara Malaysia, Kedah

011-16590264

ermieramokhtar@gmail.com

Sekiranya anda mempunyai sebarang soalan berkaitan kelulusan Etika atau sebarang pertanyaan dan masalah berkaitan kajian ini, sila hubungi;

Encik Mohamad Fadzil Samiran

Setiausaha Jawatankuasa Etika Penyelidikan UUM Pusat Pengurusan Penyelidikan dan Inovasi (RIMC) Universiti Utara Malaysia

No. Tel: 04-928 4776/4766

Email: mfadzil@uum.edu.my

KERAHSIAN

Maklumat yang anda berikan akan dirahsiakan oleh kakitangan kajian, lanya tidak akan dedahkan secara umum melainkan jika ia dikehendaki oleh undang-undang.

Data yang diperolehi dari kajian ini tidak akan mengenalpasti anda secara perseorangan. Hasil kajian mungkin akan diterbitkan untuk tujuan perkongsian ilmu.

Semua borang kajian dan data yang anda berikan mungkin akan disemak oleh pihak penyelidik, Lembaga Etika kajian ini dan pihak berkuasa regulatori bagi tujuan mengesahkan prosedur dan/atau data kajian klinikal. Maklumat anda akan disimpan dalam komputer dan hanya kakitangan kajian yang dibolehkan sahaja dibenarkan untuk mendapatkan dan memproses data tersebut.

Dengan menandatangani borang persetujuan ini, anda membenarkan penelitian rekod, penyimpanan maklumat dan pemprosesan data seperti yang dihuraikan di atas.

TANDATANGAN

Untuk dimasukkan ke dalam kajian ini, anda atau wakil sah anda mesti menandatangani serta mencatatkan tarikh halaman tandatangan

Appendix L: Sample of Rules and Regulations Form

USABILITY TESTING ON MSL MOBILE APPLICATION FOR HEARING IMPAIRED ALPHA GENERATION: OBSERVATION

OBJECTIVES OF USER EXPERIENCE TESTING:

1. To validate the design principles based on the user experience method
2. To ensure the MSL mobile application can evoke the cognitive ability among the HI alpha generation

OBSERVATION DETAILS:

1. **Observation Venue**: Computer Lab, Sekolah Pendidikan Khas Sungai Petani, Kedah, Malaysia.
2. **Preparation Time**: 9.30 am – 10.00 am
3. **Observation Time**: 10.00 am – 12.00 pm
4. List of Participants:
    a. Muhammad Amirul Danish Bin Abdullah
    b. Nurul Izzah Binti Mohd Shokri
    c. Intan Suraya
    d. Muhammad Iskandar Rayyan Bin Hasnawi
    e. Muhammad Mustaqim Bin Muhammad Naim
5. **Instructors Involved**: Siti Norshahila Binti Mohamad Khir
6. **Facilitators Involved (Observers)**:
    a. Ermiera Shafika Binti Mokhtar
    b. Dr Azizah Binti Che Omar

7. **Procedures of User Experience Testing Checklist** *(To be filled in by the program supervisor)*

No	Procedures	Comply (/)	Not Comply (X)
1	Facilitators prepare the consent forms for the participants.		
2	Facilitators only allow the participants with signed consent forms to join the observation.		
3	Facilitators, instructors, and participants follow the standard operating procedures (SOP) of Covid-19 by		

	wearing masks, 1-meter physical social distancing, and providing hand sanitizers.		
4	Facilitators prepare the tablets associated with the mobile application and set the cameras for recording		
5	Introduce the facilitators through flashcards and activities with the instructors.		
6	The instructors describe the purpose of the research and explain to the participants about the mobile application.		
7	Facilitators and instructors demonstrate the MSL mobile application to the participants.		
8	Ask the participants any questions before starting the observation and notify the participants the sessions will be recorded.		
9	Provide the participants with the card with (Stop!) and (Done) for them to initiate whether want to stop or done exploring the application.		
10	Give the participants the cards with emoticons for them to initiate their feelings when using the MSL mobile applications.		
11	Tell the participants that they can quit at any time if they are not comfortable.		
12	Tell the participants they can start whenever they are ready.		
13	Facilitators and instructors do not disturb the participants during the observation.		
14	Facilitators and instructors do not go near the participants during the observation.		
15	Facilitators allow the participants to end the session at any time.		

Appendix M: Sample of Evaluation Checklist

No	Proposed Design Principles for Malay Sign Language Mobile Application for Hearing-Impaired Alpha Generation	Description	Satisfy (/) or Not Satisfy (X)	Group 1	Group 2	Observation
Usability Heuristics for Mobile Application (1): Visibility of the system status						
1	All screens should be provided with the instructions for the HI alpha generations to be aware of their current states.	All screens should have the instructions or titles of the screens for the HI alpha generations to be aware of their current states and avoid them from being lost in the applications.				
Usability Heuristics for Mobile Application (2): Match between system and real world						
2	The sign language learning contents provided should follow the local education standards for the HI alpha generations.	The contents of the sign language learning provided in the applications should follow the local education standards to prevent the HI alpha generations from being confused about the learning contents that are different from their learning at school.				
Usability Heuristics for Mobile Application (3): User Control and Freedom						
3	The MSL mobile applications should allow the HI alpha generations to leave the applications anytime.	The HI alpha generations quickly get bored and distracted in a particular situation. Thus, they need to be given the flexibility in controlling the applications, such as leaving the applications at any screen they want to stop exploring.				
Usability Heuristics for Mobile Application (4): Consistency and Standard						

4	The quizzes or exercises provided must be coherent with the contents of the video learning.	As additional features to assess the HI alpha generation's cognitive ability, quizzes or extra exercises could be provided. Still, the exercises should be similar to the video learning content to avoid misunderstanding.				
5	The text fonts used in the MSL mobile applications should follow the local education standard font types and sizes.	As for sign language learning, content should follow the standard font, such as Comic Sans or Century Gothics font. Besides, the sizes of the fonts should be standardized and consistent for all screens.				
6	The sizes and quality of the graphics, videos, and animations provided in the MSL mobile applications should be maximized and consistent.	The HI alpha generations tend to attract multimedia elements such as video, graphics, and animation rather than text. Using images and pictures can enhance their memorability. Thus, providing high-quality multimedia elements in the MSL mobile applications is advisable.				
Usability Heuristics for Mobile Application (5): Error Prevention						
7	Timely feedback should be provided in the MSL mobile applications through the pop-out dialogue to catch the attention of the HI alpha generations.	Every action made by the users should be associated with the feedback through pop-out dialogue to avoid being lost in the application. For example, an alert should be provided with minimal options to prevent them from making massive mistakes.				
Usability Heuristics for Mobile Application (6): Recognition Rather than Recall						
8	The button in the MSL mobile application should be clickable and consistent according to the functionalities.	Buttons or menus should be consistent, and the colors should follow the standards. Avoid using texts and images as buttons. The design of the button should be clickable and avoid blinking button design. The button should be associated with the labels. The				

		colors of the button should be consistent and follow the standard that has been imposed.				
9	The characters used in designing the MSL mobile applications should be recognizable and suitable to the contexts of the HI alpha generations.	It is advisable to use characters recognizable by the alpha generations, such as the trending cartoons or the figure they know to attract their attention and grow their interest in the application.				
Usability Heuristics for Mobile Application (7): Flexibility and Efficiency of Use						
10	Ensure flexibility of navigation for the HI alpha generations in exploring the MSL mobile application	The HI alpha generations are the children that easily get distracted by their emotions. Thus, they need flexibility in the navigation of every task that is assigned to them. For example, the HI alpha generations might get pressured to answer questions they are unfamiliar with. Thus, the MSL mobile application should give the flexibility to skip the questions.				
Usability Heuristics for Mobile Application (8): Aesthetic and Minimalist Design						
11	Keep the interface design of the MSL mobile application simple and less crowded to minimize the cognitive ability among the HI alpha generations.	The interface design should be simple and less crowded. According to the experts, having only 5-7 elements within a screen is good for enhancing the cognitive ability among HI alpha generations.				
12	The interface's color for the MSL mobile application should be minimal but attractive with a good color combination.	In the context of the HI alpha generations, the interface of the MSL mobile applications should be bright and attractive to attract their attention but less crowded. It is good to have a maximum three-color combination or use the earth tone color suggested by the users' representatives through UCD.				

Usability Heuristics for Mobile Application (9): Help Users Recognize and Recover from Errors						
13	The MSL mobile application should provide the redo and undo button for the alpha generations to recover from mistakes.	The MSL mobile application should provide 'Redo' and 'Undo' buttons to help the HI alpha generations to have a smooth experience using the applications. They tend to make massive mistakes while using the applications and cause frustration.				
Usability Heuristics for Mobile Application (10): Help and Documentation						
14	The manuals can be an option for the HI alpha generations to assist them in using the MSL mobile applications.	The video tutorials can be associated with the MSL mobile applications for the HI alpha generations referred to for help.				
Usability Heuristics for Mobile Application (11): Selection Driven Commands						
15	The click-and-play functions should be maximized in designing the MSL mobile applications for HI alpha generations.	Optimizing the usage of buttons and providing click-play functions is advisable to avoid the HI alpha generations making massive mistakes when interacting with the applications. The use buttons should be fully utilized according to the functionalities.				
Usability Heuristics for Mobile Application (12): Visual Representation						
16	Use more multimedia elements than text and static images in designing the MSL mobile applications since the HI alpha generations rely more on graphics and visuals than plain texts.	The HI alpha generations are attracted more to multimedia elements or visuals such as graphics, video, and animation. Thus, it is advisable to represent the elements in the MSL mobile application with the usage of the multimedia elements to catch their attention and increase their level of satisfaction in experiencing the application.				