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ABSTRACT

In the academic realm, sign language mobile apps are an exciting research area that deserves a lot of attention. These apps are largely utilised because of their low cost and convenience. However, for these apps to have a real impact, their quality should be assessed. Such an assessment will motivate app development efforts and thus present a successful development methodology for new apps. A systematic literature review (SLR) search was conducted on three academic databases, namely, Science Direct, IEEE, and WOS and identified (n=33) research related works. From the SLR, it reveals the lack of assessment of sign language mobile apps and none of these apps had undergone a quality assessment in term of standardized approach. The objective of this research is to propose a new assessment methodology to assess the quality of the Malaysian Sign Language (MSL) mobile apps. This study adopted the content expert standardized criteria which involves 17 experts using the Fuzzy Delphi method and modified Mobile App Rating Scale (MARS) using the Fuzzy-Weighted Zero Inconsistency (FWZIC) approach which involves 5 experts. The findings show that the new assessment methodology be able to outline a sturdy list of criteria for sign language mobile app development. This study is providing future researchers a comprehensive understanding of mobile app development criteria and its weight. The findings will benefit and opens up a new area where researchers and developers could work together on sign language mobile apps.

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METODOLOGI PENILAIAN KUALITI UNTUK APLIKASI MUDAH ALIH BAHASA ISYARAT MENGGUNAKAN GABUNGAN SKALA PENILAIAN APLIKASI MUDAH ALIH (MARS) DAN KRITERIA PIAWAI PAKAR KANDUNGAN.

ABSTRAK

Dalam bidang akademik, aplikasi mudah alih bahasa isyarat ialah bidang penyelidikan yang menarik yang perlu diberi perhatian. Aplikasi ini banyak dimanfaatkan disebabkan kosnya yang rendah dan keselesaannya. Walau bagaimanapun, untuk aplikasi ini memberi impak sebenar, kualitinya harus dinilai. Penilaian kualiti ini akan mendorong usaha pembangunan aplikasi dan seterusnya menggariskan satu metodologi pembangunan yang berjaya untuk pembinaan aplikasi baharu. Satu tinjauan literatur yang sistematik (SLR) telah dijalankan menggunakan tiga pangkalan data akademik, iaitu, Science Direct, IEEE, dan WOS dan mengenalpasti sebanyak (n=33) kerja penyelidikan yang berkaitan. Daripada SLR, didapati penilaian aplikasi mudah alih bahasa isyarat adalah sangat kurang dan tiada satu pun aplikasi yang telah menjalani penilaian kualiti yang standard. Objektif penyelidikan ini adalah untuk mencadangkan satu metodologi penilaian baharu untuk menilai kualiti aplikasi mudah alih Bahasa Isyarat Malaysia (BIM). Kajian ini mengguna pakai kriteria piawai pakar kandungan yang melibatkan 17 pakar menggunakan kaedah *Fuzzy Delphi* dan Skala Penilaian Aplikasi Mudah Alih (*MARS*) yang diubah suai menggunakan pendekatan *Fuzzy-Weighted Zero Inconsistency (FWZIC)* yang melibatkan 5 orang pakar. Dapatan menunjukkan bahawa metodologi penilaian baharu dapat menggariskan senarai kriteria yang kukuh untuk pembangunan aplikasi mudah alih bahasa isyarat. Kajian ini memberikan pemahaman yang komprehensif mengenai kriteria pembangunan aplikasi mudah alih dan pemberatannya kepada pengkaji di masa hadapan. Penemuan ini akan memberi manfaat dan membuka satu bidang baharu di mana penyelidik dan pembangun boleh bekerjasama dalam pembangunan aplikasi mudah alih bahasa isyarat.

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LIST OF ABBREVIATION

ASL	American Sign Language
FD	Fuzzy Delphi
FWZIC	Fuzzy-Weighted Zero Inconsistency
MSL	Malaysian Sign Language
SLR	Systematic Literature Review
WFD	World Federation of The Deaf
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter describes the research background element of this thesis and has been intended to highlight various areas and points that make a significant contribution understanding of the thesis's topic. The research background in section 1.2, which reminded the reader about the topic's origins, then continued by the problem statement in section 1.3, which discussed how the problem in this dissertation emerges. Other significant points discussed include the research objectives in section 1.4, section 1.5, the research questions, section 1.6 the research scope, research significance in section 1.7 and the operational definitions in section 1.8. The final details that summarize this thesis layout in section 1.9.

1.2 Research Background

According to World Health Organization ((WHO), 2021), it states that about 5% of the world’s population which approximately 430 million people are classified under

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the ‘hearing disabled’ and these individuals require rehabilitation to address their hearing loss. Among the 430 million over 34 million or 8% that falls into this category are children. At the individual level, hearing loss affects many elements of life. For instance, (education and employment) and (impact on society and economy) has been great challenge (Rastgoo, Kiani, & Escalera, 2020). Children with hearing problems and deafness are frequently excluded from schooling in developing nations.

Besides that, adults also face an immense rate of unemployment rate (Garramiola-Bilbao & Rodríguez-Álvarez, 2016). When compared to the general population, a higher number of people with hearing loss are working in lower levels of employment. Deaf people are often socially isolated (Amarasinghe & Wijesuriya, 2019), lonely, and stigmatized as a result of this. Leading to a lack of consciousness, the hearing disabled community's communication barrier with society continues to be a source of worry (Mahesh, Jayaprakash, & Geetha, 2017). This shows how important is to address the issues faced by these category people. With this, lip reading and sign language are the two most common ways for deaf people to communicate with others (Kumar, Kishore, Sastry, & Swamy, 2016). Whenever verbal communication is impossible, such as between people of mutually unknown languages or when one or more potential communicators are deaf, sign language can be applied to bridge the gap.

According to (Pranali Loke, 2017), sign language is widely used by deaf people all over the world, nonetheless, the relationship between deaf and hearing people has always been tense. Hand signs, gestures, facial expressions, and body

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language are used to communicate in sign language. Sign languages is like spoken languages where it evolved naturally when different groups of people interacted with one another, resulting in a wide range of variants and there are between 138 and 300 different varieties of sign language being used now all over the world based on World Federation of the Deaf ((WFD), 2020).

Examples of Sign Language that available are Bangla Sign Language (Khan et al., 2019; Shahriar, Zaman, Ahmed, Khan, & Maruf, 2017), Bahasa Isyarat Malaysia (Chuan, Sivaji, Loo, Ahmad, & Nathan, 2017; Sahid, Ismail, & Abd Ghani, 2016; Sengupta, Mallick, & Das, 2019), American Sign Language (ASL) (Bhujbal & Warhade, 2018; Dadiz, Abrasia, & Jimenez, 2017; Jin, Omar, & Jaward, 2016; Kanakri, Lo'ai, & AlHarbi, 2017; Ku, Chen, & King, 2019; Paudyal, Lee, Banerjee, & Gupta, 2017; Paudyal, Lee, Banerjee, & Gupta, 2019; Rizwan, Khan, & Imran, 2019; Samonte, Gazmin, Soriano, & Valencia, 2019; Tiku, Maloo, Ramesh, & Indra, 2020; Zanzarukiya, Jethwa, Panchasara, & Parekh, 2020), Thai Sign Language (Luangrungruang & Kokaew, 2018; Pluempitiwiriyawej, Changsnit, Chevapatr, & Ranong, 2017; Srithonratkul, Sintupetch, Saysaman, Pluempitiwiriyawej, & Chauksuvanit, 2016; Vachirapipop, Soymat, Tiraronnakul, & Hnoohom, 2017), Indonesian Sign Language (Baehaqi, Irzal, & Indiyah, 2019; Hartanto & Kartikasari, 2016; Muzahidin & Rakun, 2020), Colombian Sign Language (Villamarin, Morales, Reyes, & Sánchez, 2016), Filipino Sign Language (FSL) (Garcia, San Luis, & Samonte, 2016; Samonte et al., 2019), Arabic Sign Language (Abdallah & Fayyoumi, 2016; Ayadi, Elhadj, & Ferchichi, 2018; El-Gayyar, Ibrahim, & Wahed, 2016; Hussain, Ahsan, Iqbal, & Nadeem, 2019; Kanakri et al., 2017; Sobhan, Chowdhury, Ahsan, Mahmud, & Hasan, 2019), Brazilian Sign Language (Bhuvan et al., 2016),

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International Sign Language (Vintimilla et al., 2016), Indian sign language (Amrutha, Davis, Samrutha, Shilpa, & Chunkath, 2016; Bhujbal & Warhade, 2018; Loke, Paranjpe, Bhabal, & Kanere, 2017; Mahesh et al., 2017; Nanaware, Sahasrabudhe, Ayer, & Christo, 2018; Rao & Kishore, 2018), Sinhala Sign Language (Perera, Jayalath, Tissera, Bandara, & Thelijjagoda, 2017), Morse code (Sachdeva, Misra, Chauhan, & Dave, 2020), Lebanese Sign Language (Abou Haidar, Achkar, Salhab, Sayah, & Jobran, 2019), Ukrainian Sign Language (Olga, Valeriia, & Volodymyr, 2019), Pakistani sign language (Gul, Zehra, Shah, Javed, & Saleem, 2020), Hindi Sign Language (Deb & Bhattacharya, 2018), Turkish Sign Language (Eryiğit, Köse, Kelepir, & Eryiğit, 2016), Urdu Sign Language (Kanakri et al., 2017), English Sign Language (Kanakri et al., 2017; Khan et al., 2017) and Bengali Sign Language (Khan et al., 2017). Among these sign languages, American Sign Language (ASL) is primary language widely used all around the world and some other sign languages are adapted from ASL. According to (Hilary Bowman-Smart, 2019), even though some of these issues are widespread and societal, increasing the population who can communicate in sign languages, even if their level of communication isn't particularly strong or proficient, will go a long way toward alleviating the challenges deaf people face in their daily lives. It will also normalise the use of sign languages in a diversity of contexts, potentially creating a social environment where prejudice against the deaf is less tolerable.

Learning sign language provides many advantages for both hearing children and adults. Equipping with sign language helps people become more apprehensive of and sensitive to the needs of the individuals with hearing disabilities. Its key perks include the improvement of the learner's cognitive ability, enthusiasm to study in both

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formal and informal environments, independence and confidence, and the development of personalized learning, which assists low-performing students in attaining its objectives (Klímová, 2019). People will build a strong appreciation for deaf culture as good sign language user, and even will be able to encourage for language acceptance and understanding among others (Burton, 2013). Likewise, studying sign language also improves job options where people with hearing disabilities would be offered job opportunities (Jan Gugenheimer, 2017). As a result, this will boost community and societal awareness thus breaks down the barriers between the hearing disable individuals and hearing individuals.

However, there are number of different approaches or traditional method of learning sign language practiced. Learning sign language by reading sign language book, taking sign language lessons, attending sign language related seminars and conferences, learning from interpreters are among the regular traditional method. One of the most common causes is that language courses generally consist of a very low percentage of classroom instruction and a very high amount of individual and out-of-class learning. This makes it challenging to give students enough language practice while also attending to their specific learning needs in the classrooms (Anke Berns, 2016).

Meanwhile, the development of mobile applications is fueled by technological breakthroughs that have dramatically boosted the use of mobile phones and applications. Users are using their own mobile devices for teaching and learning practices which called as mobile learning and as a result of the shifting and integration of mobile technologies in the educational environment (Klímová, 2019).

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According to the authors of (Ku et al., 2019), mobile phones and mobile apps are already been a component of higher education in terms of teaching and learning online classes. Furthermore, the researcher in (Rizwan et al., 2019) remarked on how mobile phones can be used not only for educational purposes but also for translation and recognition purposes where it can be used on-the-go. Several mobile applications for studying specific courses using sign language have been developed over time to make learning more convenient, however before these applications are made available to end users, various tests should be conducted. They are needed to assure that it is of adequate standard, is stable, and fulfil the specified criteria or requirements.

Although there are a few existing sign language mobile learning applications (Vintimilla et al., 2016), they are often too limited and inadequate for efficient sign language learning. Therefore, there exists an imperative need for automated and efficient assessment of mobile applications for sign language where users still heavily trust either application store ratings or the content rated by the application developer. Systematic assessment is necessary to evaluate app content (Shahriar et al., 2017). This study also aimed to recognize academic barriers, motives, and recommendations related to quality evaluations, as well as to provide best practices.

Such form of assessment necessitates a significance that is more than just information and expertise, and they are frequently time-consuming and practically challenging (A. H. Alamoodi, B. B. Zaidan, & Mussab Alaa, 2020). According to the author, the slow-paced scientific procedure targeted at app evaluation, the lack of characteristics that could assist identify highly valuable apps, and the paucity of available apps that have been tested are all challenges to app quality assessments.

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Exploring this domain of evaluation was urged for a range of factors, such as the level of the knowledge in an app or content for an app (Shahriar et al., 2017), which would aid in the creation of a reliability app (Loke et al., 2017) and the consideration of strategies to ensure app quality (Ryan Lee Romero, 2019). The author adopted the MARS for assessment of their study. Health app comparison can be done using the well-known MARS scale, a standardized tool created by Queensland University of Technology. MARS is regarded as a straightforward and trustworthy tool for categorizing and rating the standard of mobile health apps. It can also be used to create a checklist for generating new, greater apps. MARS uses 23 distinct MARS items to rate apps based on engagement, functionality, aesthetics, and information quality.

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Each MARS item being graded on a 5-point scale with the following descriptors: 1-Inadequate, 2-Poor, 3-Acceptable, 4-Good, and 5-Excellent. The MARS is scored using a mean app quality total score, with MARS items operating by computing their mean scores. Due to the possibility of a Not applicable rating for an item, mean scores are utilized instead of total scores. Additionally, quality ratings that correlate to the well-known star rating system are provided using mean scores. A mean subjective quality score or individual scores for each of the subjective quality items are also possible. Application quality assurance and validating methods, architecture building for app assessment, complete audit of app quality, and a new cross platform app quality evaluation method are all needed, according to the literature (A. H. Alamoodi et al., 2020).

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1.3 Problem Statement

While observing the academic literature on sign language mobile apps, different challenged emerged. Most of these challenges have their influence (in away or other) on the quality of mobile apps. Total of three main challenges classes are observed, including, Content Challenges, Design Challenges and Functions Challenges as presented on Figure 2.4.

Each of these classes are associated with its own issues. The first challenge reported in the academic literature is concerned with Apps Content. The main issues reported in that regard includes Apps limited sign language content (Amarasinghe & Wijesuriya, 2019; Amrutha et al., 2016; Bhujbal & Warhade, 2018; Jin et al., 2016; Ku et al., 2019; Mahamud & Zishan, 2017; Samonte et al., 2019; Sobhan et al., 2019), limited features (Garcia et al., 2016; Liqing, Wenwen, Yong, Yanyan, & Guoming, 2018; Sobhan et al., 2019), focus on particular languages only (Amarasinghe & Wijesuriya, 2019; Mahamud & Zishan, 2017; Shahriar et al., 2017). This class of challenges not only affect using these sign language mobile apps by users to gain adequate knowledge to learn the sign language (Muzahidin & Rakun, 2020; Nanaware et al., 2018) but also makes their future analysis and development a difficult job to do (Baehaqi et al., 2019; Bhujbal & Warhade, 2018; Srithonratkul et al., 2016).

Second class of challenges is attributed to Design, the main issues in that regard includes the screen apps design (Deb & Bhattacharya, 2018), gesture design (Abdulla, Abdulla, Manaf, & Jarndal, 2016), and the availability of apps in certain

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platforms (Hussain et al., 2019; Sobhan et al., 2019). The third challenge identified in literature involves different elements with respect to the sign language mobile apps functions. Some of the issues in that regards includes, gesture recognition features and other functions (Nanaware et al., 2018; Neiva & Zanchettin, 2018; Rastgoo et al., 2020; Sengupta et al., 2019). These function issues have their own influence on sign language mobile apps system's performance which affect their usage over time.

It is clearly identified that sign language mobile apps can bridge a gap for communication between deaf and normal people, yet many of the literature issues reported had their impact on them. An app with many content limitations will not be appealing to users, and the same thing goes for the app design and functions. On the other hand, an app with proper content, design and functions will make users more drawn to using them for their communications with those with special needs. Yet for these mobile apps to find their ways to users, their quality should be assessed. Simply because an app which has been assessed in term of its quality either will motivate other apps development effort to update and work on their quality, and at the same time present a successful model for new apps to be developed.

While looking at academic literature, it turned out that majority of sign language mobile apps have been mainly assessed by either conducting an in-house testing and evaluation or by running these apps in different experimentations set by their developers and authors. None of these apps had undergone a quality assessment in term of standardized approach except for one study by (Ryan Lee Romero, 2019) where authors performed quality assessment on mobile apps for sign language using Mobile Apps Rating Scale (MARS). However, despite the potential of MARS as an

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assessment tool which can be used for mobile apps, especially those related to sign language, it still has its own shortcoming which does not make it by itself at least the best tool for Sign language mobile apps.

MARS was previously utilized by (Ryan Lee Romero, 2019) for quality assessment of ASL sign language mobile apps, but this approach exhibits its own shortcomings, including its reliance on subjective criteria of assessment items which only rely on user interaction with the apps producing a mean subjective value, and ignoring additional important criteria especially the ones associated with apps content. Accordingly, more quality assessment criteria are warranted for further exploration. For instance, a sign language mobile app X will be considered good if the raters feel the app is good based on their own subjective views, they might overlook the features and functions of the app which clearly also are important, because at the end of the day, user perspective is only one part of the assessment and the functions and internal features of the app also holds significant impact. Another example, if an app was considered good in term of MARS criteria, but the actual features of the app were bad and the information presented misguided users, this will reflect on its long-term usage and though it was initially deemed good, because of its content limitations, it will not be considered for official communications between normal and deaf users. Another significant issue is that MARS criteria are only determined by specific number of users (experts) who will judge the app, and since human involvement is presented, this will introduce bias, and insufficient evidence to be considered as ultimate guide to assess the app, and for that content of the app along with its design are also worthy of considering while assessing the app. Another shortcoming of MARS is that this

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assessment tool heavily relies on the mean score of the used assessment items, and it overlooked the individual importance and significance of each of these items when performing the assessment (weight) which cannot be considered as ultimate solution for assessing the apps.

Therefore, in this research we are bridging this gap of MARS assessment by infusing its criteria with ones from the academic literature linked to mobile apps content, and thereby creating a unified assessment methodology where not only subjective criteria reflecting user perspective are only considered, but also introducing a content, functions and design criteria which will be as important for consideration while assessing sign language mobile apps, and measuring their importance weights and its impact on the assessment. This research also addresses other sign language mobile apps challenges aside from MARS based on the literature.

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It was found that most of these articles identified in this research shows that majority of the works on sign language mobile apps were performed on particular countries and sign languages like the ones done on American Sign Language (*ASL*) and Indian Sign Language (*ISL*) and the room for exploring other languages are warranted (Amarasinghe & Wijesuriya, 2019; Mahamud & Zishan, 2017; Shahriar et al., 2017).

Within the scope of this research, an Asian country like Malaysia was not only lacking studies in term of academic work on sign language mobile apps except for

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(Chuan et al., 2017; Jin et al., 2016; Joseph, 2019; Sahid et al., 2016), but also the work in official Malaysian sign language did not appear much except in few works like (Chuan et al., 2017; Sahid et al., 2016; Sengupta et al., 2019). This clearly call for a motivation to work to conduct more research works in this sign language mobile apps, especially for Malaysian Sign Language (MSL or Bahasa Isyarat Malaysia). Although it was based on American Sign Language (ASL), the two languages are considered unique (Sofiah Sajap, 2020), especially given the fact that both of them presents different populations. Therefore, for several reasons mentioned above this research attempts to perform an enhanced quality assessment methodology for Sign Language mobile apps using Mobile App Rating Scale (*MARS*) criteria along with other criteria standardized and weighted from the literature reflecting two main aspects; subjectivity and objectivity and with different level of significance (*weights*) which will play a major role in the assessment procedure. This methodology is applicable to any sign language mobile apps assessment, but it was applied on case study for Malaysian Sign language mobile apps as proof of concept using different criteria and experimentations till a consensus is achieved and quality of apps are assessed and presented.

1.4 Research Questions

In order to set the direction of this research, the following research questions are raised;

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- What are the current research gaps, challenges, and research efforts on the assessment of Sign Language Mobile apps?
- What are the requirements for creating an efficient assessment methodology for Sign Language Mobile Apps?
- How effective is the proposed methodology for the assessment of sign language mobile apps?

1.5 Research Objective

This research aimed to develop a mobile apps quality assessment methodology for sign language mobile apps. The main research objectives are, as follows:

- To identify assessment methodologies, research gaps and other academic efforts on sign language mobile apps.
- To propose a new assessment methodology for sign language mobile apps based on modified MARS and content expert criteria.
- To evaluate the effectiveness of the proposed methodology using different level criteria hierarchy and experimentations.

1.6 Research Scope

This research is aimed to evaluate and select Malaysian Sign Language mobile application using the mobile apps rating scale (MARS). Therefore, few points need to be considered as the following:

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1. This research focuses on mobile application quality assessment evaluation and selection which involves only Malaysian sign language mobile app.
2. The Malaysian Sign Language mobile application used in this research is only downloaded from Google Play Store.

1.7 Research Significance

Basically, users would be able to choose the most reliable apps for them using the proposed methodology. As a result, it will be able to give the best and most reliable mobile app for learning Malaysian sign language, resulting in improved learning. The outcomes of this thesis will assist a variety of fields, including sign language and mobile app assessment studies. In the context of sign language and mobile apps, it helps to identify the challenges that arise in these studies and to address them. More reviews can be viewed in section 2.4.2 for further motivation and 2.4.3 for recommendations that are relevant to addressing this area.

1.8 Operational Definitions

Some words and definitions might not be totally clear to some readers, and a clarification for such elements is good to allow the reader to grasp what this words or phrase is intended for. Therefore, this section aims to display and clarify terms and definitions used in this research, all of them are presented in Table 1.1.

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Table 1.1

Operational definition

Chapter	Item	Operational definition
1	Research significance	The importance of your research
	Hearing disabled	A person who is not able to hear as well as someone with normal hearing
	Deaf	Hearing loss that precludes a person from understanding spoken language
	MARS	The Mobile Application Rating Scale (MARS) is the most widely used scale for evaluating the quality and content of MHA
2	SLR	A systematic literature review (SLR) identifies, selects and critically appraises research in order to answer a clearly formulated question
	Taxonomy	Taxonomy is the science of naming, describing and classifying an element
3	Criterion	A principle or standard by which something may be judged or decided

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1.9 Thesis Layout

This thesis is divided into five chapters, the first of which featured background information 1.2 on sign language and mobile apps. Following that, a discussion of the problem statement 1.3, followed by the research questions 1.4, research objective 1.5, scope 1.6, research significance 1.7, operational definition 1.8 and 1.9 thesis layout.

Chapter Two: The sign language and mobile application research were investigated in depth in chapter two. This involves outlining the keywords (Queries) that will be utilized to look into the existing literature. To evaluate and examine the literature in order to develop taxonomy 2.3, a (SLR) Systematic Literature Review

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process is adapted. The articles chosen were divided to map out this field of evaluation and extract key features such as challenges, motivations and recommendation in section 2.4 which later allowed to design our research gaps and problems. Methodological aspects were presented in 2.5 on previous study and lastly literature synthesis is shown in section 2.6.

Chapter Three: The study technique and the research methodology are established and described in this chapter. Furthermore, the research process is divided into four phases: the investigation phase 3.2, criteria phase 3.3, development phase 3.4 and validation phase in section 3.5. In the investigation phase, it begins by diving into the literature by utilizing a well-known research protocol for a Systematic Literature Review, Criteria phase explains about the criteria that has been collected, standardize and weighted for the matrix development, development phase is where the development for assessment and selection is taken place and the validation phase is where to assess prior work in order to make a quick assessment of the techniques.

Chapter Four: This chapter focuses on the application of the proposed methodology. This was started with the mobile apps' identification on 4.2, 4.3 Malaysian Sign Language related mobile apps is discussed. This is followed by main and sub 4.4 Set of Criteria presentation, 4.5 Results of criteria standardization , 4.6 Mobile Apps Rating Scale (MARS), 4.7 Matrix for Main Criteria and sub criteria and 4.8 Weighting method is explained.

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Chapter Five: A complete methodological analysis is presented in chapter five. Analysis of Fuzzy Delphi, analysis of FWZIC and analysis of mobile assessment is discussed separately in section 5.2 Methodology Analysis. Lastly, 5.3 Discussion, 5.4 Implications, 5.5 Limitations, 5.6 Future Research and 5.7 Conclusion is presented to show the summary of the entire dissertation.

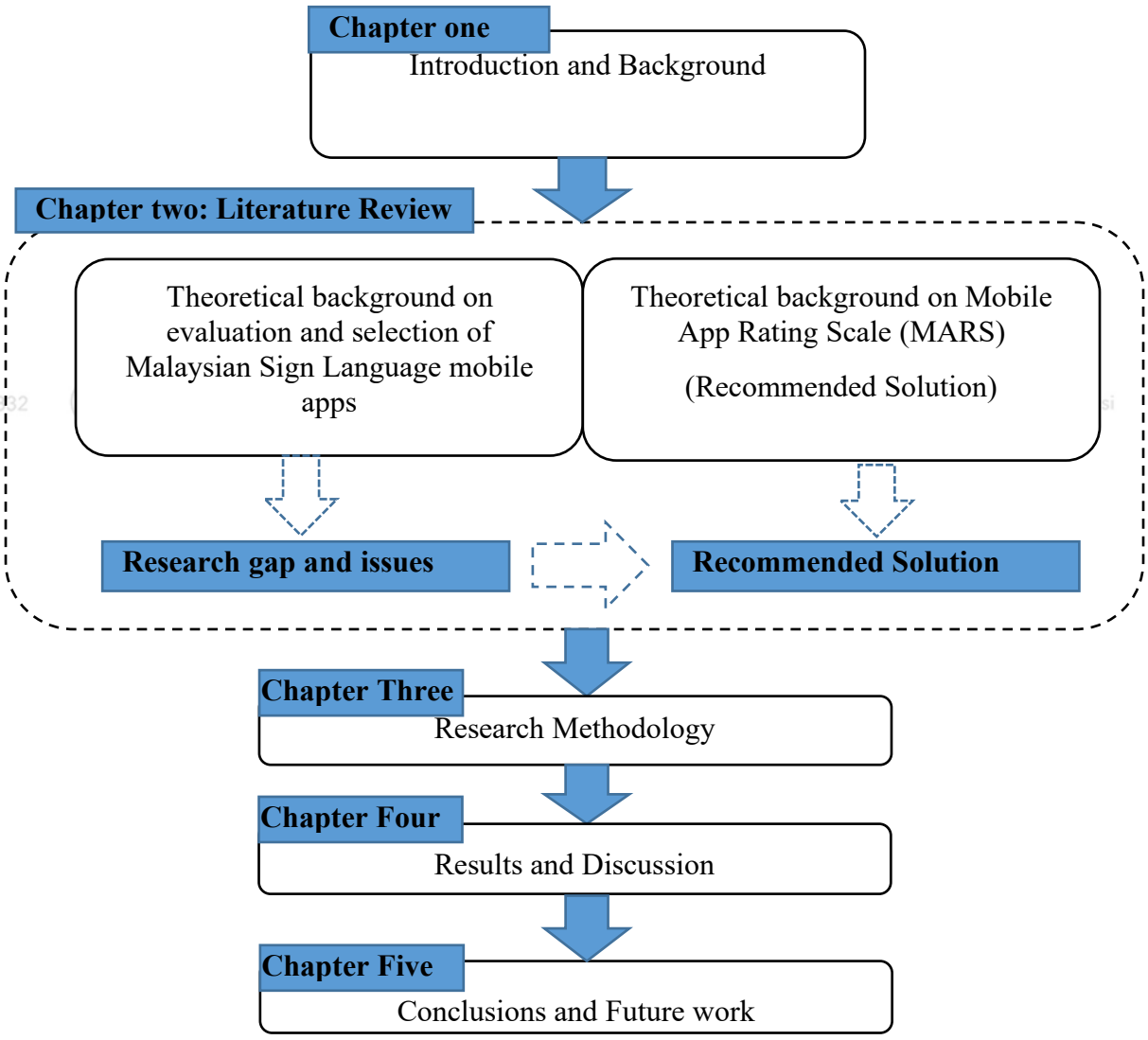

Figure 1.1. Structure of the Dissertation

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