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AFFECTIVE FOUR DIMENSIONAL DESIGN PRINCIPLES OF MOBILE MATHEMATICS APPLICATION FOR PRIMARY SCHOOL LOW VISION LEARNERS

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Abstrak

Fokus kajian ini berkaitan dengan teknologi yang direka khusus untuk orang kurang upaya (OKU), yang dipanggil Teknologi Assistif (AT). Kandungan pendidikan dalam aplikasi mudah alih afektif adalah terhad, terutamanya untuk pelajar- pelajar berpenglihatan terhad. Banyak aplikasi mudah alih tidak memenuhi keperluan afektif atau emosi pelajar- pelajar berpenglihatan terhad. Kajian awal telah membuktikan bahawa aplikasi kandungan yang ada kurang memenuhi keperluan pelajar- pelajar berpenglihatan terhad dari segi komponen afektif. Oleh itu, kajian ini mencadangkan satu set prinsip reka bentuk afektif bagi aplikasi mudah alih untuk pelajar- pelajar berpenglihatan terhad, dinamakan sebagai Prinsip Rekabentuk Afektif Empat Dimensi Aplikasi Matematik Mudah Alih untuk Pelajar Sekolah Rendah Berpenglihatan Terhad . Dua (2) objektif dibentuk; untuk membina prinsip reka bentuk afektif melalui analisis perbandingan dan pendekatan reka bentuk berpusatkan pengguna dan untuk mengesahkan prinsip reka bentuk afektif melalui prototaip, semakan pakar, dan ujian pengalaman pengguna.. Bagi mencapai objektif kajian dua (2) pendekatan kajian telah digunakan iaitu temubual dan pemerhatian. Metodologi Penyelidikan Sains Rekabentuk telah diadaptasi. Empat (4) komponen Prinsip Reka Bentuk Afektif telah dibina berdasarkan komponen empat dimensi afektif: emosi, perasaan, pemikiran, dan tindakan yang menghasilkan lapan (8) elemen: kebolehan mengingat, motivasi, minat, kebahagiaan, persepsi positif, keadaan minda positif, navigasi, dan interaksi. Cadangan tiga belas (13) prinsip reka bentuk afektif telah disemak oleh enam (6) pakar dan disahkan melalui pembangunan prototaip. Prototaip ini juga telah melalui ujian pengalaman pengguna yang terdiri daripada tujuh (7) orang murid berpenglihatan terhad di sekolah rendah. Pakar meluluskan prinsip-prinsip rekabentuk yang diusulkan. Prototaip mencadangkan pembangun baru dan pembangun bukan teknikal harus menggunakan prinsip rekabentuk afektif sebagai garis panduan mereka untuk pembangunan aplikasi mudah alih. Ujian pengalaman pengguna menunjukkan kajian ini memenuhi keperluan pelajar- pelajar berpenglihatan terhad dari segi afektif. Keputusan ini menunjukkan bahawa Prinsip Reka Bentuk Afektif Empat Dimensi dalam kajian ini berguna untuk pembangunan kandungan aplikasi mudah alih dan memberikan sumbangan dari segi teori dan praktikal bagi memastikan peluang pembelajaran yang saksama untuk pelajar-pelajar berpenglihatan terhad.

Kata Kunci: Interaksi manusia komputer mudah alih**,** Teknologi asistif (AT), Reka bentuk afektif, Pendekatan reka sbentuk berpusatkan pengguna, Pengalaman pengguna, Penglihatan terhad.

Abstract

The focus of this study relates to technology that is purposely designed for people with disabilities (PWDs), which is called Assistive Technology (AT). The educational content in affective mobile apps is scarce, especially for low vision learners. Many mobile applications do not address the low vision learners' affective or emotional needs. Preliminary studies have proven that available content applications lack to cater to the needs of low vision learners in terms of affective components. Hence, this study proposes a set of affective four dimensional design principles in a mobile application for low vision learners, named Affective Four Dimensional Design Principles of Mobile Mathematics Application for Primary School Low Vision Learners. Two (2) specific objectives are formulated which are; to construct the affective design principles through comparative analysis and a user-centred desin approach and to validate the affective design principles through prototyping, expert review, and user experience testing. To achieve the objectives, two (2) design approach utilised in this study, interview and observation. The Design Science Research Methodology (DSRM) has been adopted. Four (4) components of Affective four dimensional design principles have been constructed based on the affective four dimensional component: emotion, feeling, thought, and action which derived eight (8) elements: memorable, motivational, interest, happiness, positive perception, positive mind state, navigation, and interaction The proposed of thirteen (13) affective four dimensional design principles has been reviewed by six (6) experts and validated through prototyping. The prototype has been undergo the user experience testing on seven (7) low vision learners of primary school. The experts approved the proposed design principles in this study suggests novice and non-technical developers should apply affective four dimensional design principles as their guidelines for mobile application development. User experience testing shows that this study meets low vision learners in terms of affective. These results show that Affective four dimensional design principles Four Dimensional are useful mobile content application development which also provide theoretical and practical contributions to ensure equitable learning opportunities for low vision learners.

Keywords: Mobile human-computer interaction, Assistive technology (AT), Affective design,user-centered design approach, User experience, Low vision**.**

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List of Abbreviations

AMM4LV	Affective Mobile Mathematics For Low Vision
AT	Assistive Technology
CCTV	Close Circuit Television
DSRM	Design Science Research Methodology
ERAS	Educational Research Application System
LV	Low Vision
MOE	Ministry of Education
PWDs	Person With Disabilities
SNS	Special Need Student
UCD	User Centred Design
VI	Visual Impairment
WAI	Web Accessibility Initiative
WHO	World Health Organisation
W3C	World Wide Web Consortium
ZRP	Zero Reject Policy

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CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter explains the background of the study, which exposes the issues that led to the motivation aspects of this study. In addition, this chapter also highlights the research motivation, preliminary study, objectives, research questions, significance of the study, scope of study, and operational definitions.

1.2 Background of the study

Mobile Human-Computer Interaction (HCI) devices like portable computers, mobile phones, and wearable smart technologies, have spawned a new demand in which users appear to be able to communicate psychological and cognitive states with mobile and online monitoring and archiving systems (Moghimi et al., 2017).

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The increasing focus on the significance of a user's emotional state is reflected in recent developments in the field of education, such as the development of emotion-recognition robots to aid children with special needs in the classroom (Zamin et al., 2018) and the detection of a student's frustration through educational game-based learning (Henderson et al., 2019).

In computer science, researchers examine how users' emotions affect software to use to improve user experience (Riseberg et al., 1998).

Therefore, Picard (1997) coined the term "Affective Computing," which describes techniques in computational systems to recognize and react to human feelings through

computer interfaces. Moreover, affective design is the method of making a product to elicit a particular emotional response from the target audience (Coetzer, 2017).

Affective elements were previously seen as a source of unnecessary cognitive strain, hence their use in multimedia learning was prohibited (Uzun & Yldrm, 2018). However, recent research (Liew et al., 2017) suggests that using multimedia with affective elements in learning can be beneficial in providing motivation as it can improve learning.

Thus, appropriate design principles for mobile learning applications should be extended effectively. The need for affective four dimensional design principles that promote students' motivation and mediate student to have a better understanding of concepts in mathematics subjects through affective four dimensional design principles implemented in the mobile application have motivated this study.

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Thus, this study has made use of affective four dimensional design principles being implemented in the assistive technology (AT) to help low vision (LV) learners as well as for assisting special needs teachers so the quality of special education in Malaysia can be enhanced.

Whereas mathematics act as a core subject that is vital and closely related to daily life.

Furthermore, mathematics subject incorporates conceptual and practical understanding (Azid et al., 2020). Thus, mathematics becomes more challenging for low vision (LV) learners as it encourages critical thinking in problem-solving.

Mathematics is usually represented as a visual material that affects their performance of arithmetic operations that exist as a symbol in mathematics subject (Daroni et al., 2018). Therefore, choosing suitable teaching methods will contribute to a greater understanding of mathematics among students, especially for LV learners.

Mobile learning or m- learning offers the measures of benefits of multimedia or mobile learning. Teachers need to be equipped with the technology approach. Therefore, they should equip themselves with relevant technology skills and approaches to ensure their teaching is effective.

For this study, a set of affective four dimensional design principles that are specifically designed for primary schools of LV learners has been applied in the development of the mobile application. In those schools, the mobile application aims to aid the LV learners in learning the mathematics subject. Since the advancement of technology in AT is demanding especially for educational purposes, there is a need to identify the relevant affective four dimensional design principles of the accessible mobile applications for visual disabilities. Hence the affective four dimensional design principles in the mobile application referred to the use of AT in increasing the accessibilities for LV learners in learning mathematics. However, the existing software development seems not to be deployed to the need of special people (Augusto et al., 2018). Hence, affective four dimensional design principles have been developed to reach out to many LV learners.

Since the affective four dimensional design principles and their benefits are relevant for LV learners to apply in solving the mathematics problem in their studies, this study

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has applied them in the mobile application. Through the mobile application, the LV learners can understand the concepts and helps them in problem-solving.

1.3 Research Motivation

There are two aspects motivating this study to take off: There are (i) the implementation of the government policies in special education in Malaysia, and (ii) the importance of affective design in mobile learning.

1.3.1 The Implementation of The Government Policies in Special Education in Malaysia

Education is an inherent right which compromise by every individual despite his or her condition and background (Nasir & Efendi, 2016). This includes children with disabilities since they will have to take part in decision-making and participate along with society. According to Dr. Maszlee Malik, the former Minister of Education of Malaysia in protecting the educational right of disabilities students, while providing education to all children in Malaysia, including children with disabilities and undocumented children, the government has introduced an inclusive education policy known as the ‘Zero Reject Policy' (ZRP) in stages throughout 2019 (Rashid, 2018). The Ministry of Education (MOE) aims to have 75% of special needs students (SNS) attending the Inclusive Education Program which allows them to study alongside mainstream students by 2023 (BERNAMA, 2018). The Malaysian government is committed to this policy, as seen by the RM23 million set aside in the upcoming 2020 budget to make schools more accessible to people with disabilities (Times, 2019).

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The Special Education Division (Kannan, 2018) argues that the ZRP is a better policy when it comes to providing students with special needs with the quality education they deserve. Lee Chong Hui (2019), reports that 10,948 special needs students (SNS) have enrolled in schools around the country since the policy's inception. This policy is not "simply a picture frame on the wall" since it gives parents with SNS hope that they can give their children a good education at par with others.

Thus, the objective of the ZRP is in line with the vision of the Malaysia Education Blueprint 2013-2015 (2017), which provides access to education for all children in Malaysia and seeks an increase in the number of special needs students enrolled in mainstream schools throughout the country. Hence, the implementation of ZRP has motivated this study to take off as SNS needs to adapt with the general student in their studies. The development of specialized mobile applications implementing affective four dimensional design principles will motivate them to easily access learning material and have the same understanding of the concept same as the general student regardless of their disabilities.

1.3.2 Current State of Disabled People in Malaysia

There are 15% of the world's population is disabled (World Bank, 2020). The incidence of impairment is substantially higher in low-income countries. Between 110 million and 190 million people worldwide have major disabilities, including at least 93 million children (UNICEF, 2020). Visual impairment (VI) doubled from 45 million in 1996 to 76 million in 2020. According to the 2018 Yearly Statistics Report from the Department of Statistics Malaysia (DoSM) under the Malaysian Welfare Department, 409,269 disabled people were officially registered in December 2018. As of December

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2016, there were 36,692 registered VI people, and then the number increased to 40,466 in December 2017 (Table 1.1).

Table 1.1

Registered Disabled People According to Types of Disability, 2016-2020

Type of Disability	Year					
	2016	2017	2018	2019	2020	2021-2023
Visual Impairment	**36,692**	**40,466**	**36,171**	**43,576**	**51,306**	**55,240**
Hearing Impairment	31,937	34,280	44,523	35,991	39,935	42,652
Physical Impairment	142,600	159,674	179,222	173,587	209,982	219,218
Learning Disabilities	143,334	157,714	170,269	169,853	199,352	235,731
Speech Problem	2,104	2,355	2,572	2,534	2,948	3,397
Mental Problem	33,518	37,537	41,218	40,570	47,981	52,412
Others	19,084	21,232	23,415	22,837	27,087	28,887
Total	409,269	453,258	497,390	488,948	578,591	637,537

Source: Department of Social Welfare Malaysia

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Referring to the facts in Table 1.1, it could be concluded that from the year 2016 until 2018, the trend of registered VI people in Malaysia have been fluctuated and started to increase from 2018 to 2020. After that from the year 2021 until 2023, there is no specific data on each year, however, on the latest update by the Department of Social Welfare Malaysia the number increased in each type of disability listed especially the concern of this study, which is visual impairment. This shows the increase of registered VI in Malaysia.

On the other hand, in terms of employment reported by the Social Welfare Department of Malaysia based on recent statistics in December 2020, there is only 40 jobs appointment by PWD in the government sector after 3,615 applications have been

made by the PWD (Employment & Labour Statistics of Malaysia, 2020). However, the Government of Malaysia, on the other hand, has implemented a policy that states that people with disabilities (PWDs) have the right to access employment on the same basis as people who do not have disabilities, in accordance with the PWD Act 2008 and the National Action Plan for People with Disabilities 2016-2022. Thus, this study believes, the failure to integrate people with disabilities into Malaysia's workforce has resulted in the potential of PWDs not been fully utilized.

1.3.3 The Importance of Affective Design in Mobile Learning

Affective design is an attempt to determine the emotional links that exist between consumers and products, as well as an investigation of the perceptual design components that are associated with the affective characteristics of the products. Affective design also includes the study of the emotional connections that exist between consumers and products (Norman 2004). For example, the affective design that was employed in a mobile health application in South Africa. This application's goal was to emotionally engage people living in rural communities (Coetzer, 2017). The application utilizes community legend-based interactive agents. Hence, the mobile health application evokes an emotional response from the user and encourages frequent logins for medical report updates, appointment scheduling, and health information. Therefore, a mobile application with a good affective design able to provoke psychological feelings and boost emotional enjoyment.

Another study by Bhandari et al. (2017) found that an application interface design can improve an individual's everyday chores or increase their competency. This improves the user's mobile application experience. So, this study uses affective design in the

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mobile application to improve LV learners' mathematics learning experience. Using mobile learning, students with low vision may be able to improve their learning competency in mathematics subject.

In his paper Education 4.0: The Future of Learning (2017), Fisk lists nine trends for Education 4.0, the first of which is the necessity for diverse times and locations for learning. E-learning technologies provide remote, self-paced learning anytime and anywhere (Crescente & Lee, 2011). E-learning is computer-aided learning, and mobile learning uses the internet, computer, visual, and audio devices to teach and learn (Oyelere et al., 2016).

Nevertheless, mobile learning is defined as m-learning, u-learning, and learning while mobile, personalized learning, anytime or anyplace learning, and portable learning (Abd Karim et al., 2018). Mobile learning could also improve 21st-century education by using digital technologies. Students learn better with mobile learning (Singh et al., 2017). Thus, this study is motivated to use affective design in mobile mathematics for LV learners.

1.3.4 Summary of Research Motivation

The implementation of policy in special need education has benefited many students and their parents. Hence, these implementations of policies in providing equal rights for SNS at the national level might be a trigger for the developers, and researchers to lend a hand and make innovations based on the needs to cater to disabilities. To provide effective learning to SNS, appropriate learning materials for a better

understanding should be initiated to provide a better understanding of their learning process.

Multimedia and technology have been integrated into education systems for decades as many developers acknowledge the advantages of enjoyable and interactive learning. Teachers and academics employ technology in their lessons. So, using affective design concepts to meet LV learners' requirements makes learning more effective and helps them.

1.4 Problem Background

Special needs education in Malaysia is striving to be in line with the global trend toward inclusive education by officially beginning to integrate students with special needs in mainstream education. This is initiated by the United Nations (UN) policies to affirm that education is for all and promotes equal education regardless of the condition or disabilities of the person. However, to get aligned with the general students requires a lot of modifications and improvement in learning tools that can assist the special needs student to receive the same amount of understanding in the learning process. It requires the special needs student to be equipped with accessible learning tools such as accessible mobile applications to cater to the needs of LV learners in the learning process to get in line with the general students.

An initial investigation on affective four dimensional mathematics model for LV learners by Aziz et al. (2019) found that most affective learning models just detect user emotions rather than providing emotion to them. Hence, the existing mobile applications lack in affective design.

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Nonetheless, mobile application usage can improve students' positive learning. Table 1.2 shows existing mobile applications and their targeted learners.

Table 1.2

Existing Mobile Applications with Targeted Learners

NO.	Author	Name of Application	Target learners
1.	(Ahmetovic et al., 2021)	WordMelodies: an Inclusive Mobile App Supporting the Acquisition of Literacy Skills	Low Vision and Blind
2.	(Diskapama & Fauzi, 2021)	Kai Access: Mobile Application Using Inclusive Design to Increase Accessibility for Patients Disability of Vision	Low Vision
3.	(Ahmetovic et al., 2021).	MusA: artwork accessibility through augmented reality for people with low	Low Vision
4.	(Thakur et al., 2021).	MagVi: Towards Saliency-Driven Video Magnification Application for the People with Low Vision	Low Vision
5.	(Othman et al., 2020)	Serious Game for Low Vision Children.	Low Vision
6.	(Madrigal-Cadavid et al., 2020)	FarmaceuticApp: Design and development of a mobile app of drug information for people with visual impairment.	Low Vision and Blind
7.	(Pagano et al., 2020)	mySugr: Accessibility of Visual Content in Mobile Apps: Insights from Visually Impaired Users	Low Vision and Blind
8.	(Ceccarini, & Prandi, 2019)	Tourism for All: A mobile application to assist visually impaired users in enjoying tourist services.	Low Vision and Blind
9.	(Mohamad et al., 2018)	Sejahtera Lestari: Mobile Health Application for Visual Impaired Individual	Low Vision and Blind
10.	(Ghidini et al., 2016)	All Appointment: Developing apps for visually impaired people: Lessons learned from practice	Low Vision and Blind

Based on Table 1.2 clearly shows that most of the targeted users are visually impaired including low vision. However, there are a lot of existing mobile applications but not fully accessible to those who suffer from visual impairment, specifically low vision (Acosta-Vargas et al., 2020). Hence, a comparative analysis of the problems related to

the accessibility components in ten existing mobile applications has been analysed by adopting the accessibility issues outlined by Diskapama and Fauzi (2021). In their study, they only focus on the accessibility issues of user interfaces. The issues outlined are depicted in Table 1.3 and have been adopted in this study to identify the problems related to accessibility issues based on the ten existing mobile applications.

Table 1.3

Accessibility Problems of Existing Mobile Application

Accessibility problems of existing mobile application	1	2	3	4	5	6	7	8	9	10
Text size	/	/	/	/	/	/	/	/		/
Text color										/
Background color					/					/
Icon	/					/			/	
Button	/	/	/				/	/	/	

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Based on Table 1.3, the problems highlighted are the common problems related to accessibility are text size, text color, graphics, background color, icon, and button (Diskapama & Fauzi, 2021). The most common problem detected in the existing design is the text size. Legge (2016) suggested to enlarge the physical character size can increase the desirability of LV learners in digital reading. In addition, text displays many opportunities in enhancing the accessibility of reading for LV learners (Rayar et al., 2020). Hence, based on the interfaces provided in the ten existing studies, and through the discussion section of the studies, there are still issues related to accessibility. This means that there are tons number of people who cannot easily be accessible with the application, especially student with LV in engaging the digital

learning aid to study specifically in mathematics subjects that require critical thinking in the problem solving (Benton et al., 2018).

The Industrial Revolution 4.0 explosion has affected education to align with 21st-century digital learning environments (Mahmood & Hussin, 2018). Hence, expanding digital learning alternatives makes learning progress harder for students with visual impairments (VI) and their teachers (Asebriy et al., 2018). Digital learning may widen the digital skills gap between LV students and other students (Ramos & de Andrade, 2016). According to the World Health Organization (WHO, 2018), even in sophisticated nations, a lack of suitable resources and good assistive technology may prevent many students with LV from using new technology and e-devices to learn mathematics at school (Simui et al., 2018). Thus, accessible technology has long been a renowned topic in special education and rehabilitation (Scherer, 2005).

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To enhance the accessibility of new technology that cater to the needs of LV learners, the affective approach to design principles has been used in this study. In addition, the development of affective four dimensional design principles is growing rapidly, and it has positively impacted Assistive Technology (AT) development and has been applied in various areas such as multimedia studies (Taharim et al., 2018), engineering (Balters & Steinert, 2017), health (Alfaras et al., 2020), and education (Higley, 2019).

The development of affective four dimensional design principles in a mobile learning application is very helpful in providing teachers with relevant digital learning aid for LV. Thus, this study grounds on determining the most relevant affective four dimensional design principles to be used in the mobile application for inclusive

technology designed for LV learners. This suggests that LV learners urgently need affective design in educational content. Both Preliminary I and II interviews demonstrated an interest in improving affective design, noting that the mobile application is for LV learners.

1.5 Preliminary Study

A preliminary study has been conducted to aim for the confirmation of the research problem by conducting a need analysis. The need of analysis is the process of identifying and evaluating the needs of the community, which results to a gap between "what is" and "what should be" (Swatek, 2014). The importance of identification is a process of describing problems of a specified community or population and proposing possible solutions to the identified problem.

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To determine the nature of the research problem, two preliminary investigations have been carried out. In the first study, the researcher gathered the opinions of experts on mobile applications designed to aid students with LV in the educational setting. It was then followed by a second study that was carried out involving the perspectives of LV experts. The compilation of preliminary research, both of which involve specialists in low vision, are described in the section titled *preliminary study I* and *preliminary study II* respectively. The findings of these preliminary studies provide additional evidence that highlights the importance of this study.

1.5.1 Preliminary Study I

The primary goals of this preliminary study are (i) to learn more about the current state of mobile applications for low vision learners and (ii) to better understand the elements that contribute to the need for mobile applications for LV learners in primary school. As a result, two respondents who are content experts participated in a series of interviews. Both were addressed as R1 and R2 are mathematics teachers, but they work at different primary special needs schools. This interview with the content experts was conducted separately and at a different location. There are a total of 12 questions as listed in Table 1.4 were asked in a semi-structured format.

Table 1.4

List of Interview Questions

Scope	Questions
Learning material	Q1: Are the LV learners exposed to digital learning material?
	Q2: Are the LV learners exposed to the utilization of mobile devices?
	Q3: Are the LV learners exposed to mobile applications specifically designed for LV learners?
	Q4: Does the usually used digital platform (application/ courseware) contain audio, graphics, animation, and video?
	Q5: Does the digital platform (application/ courseware) have the features to assist the low vision learners during the learning process?
Availability of mobile application	Q6: Is there any standardized mobile applications designed for LV learner provided by MOE for special needs school?
	Q7: Are the mobile applications available in the market suitable for LV learners?
Needs of mobile application	Q8: Do you recommend a proper mobile application that is specifically designed for LV learners?
Subject requirement	Q9: What is the most critical topic in teaching mathematics?
	Q10: Why is that particular topic considered a difficult topic among students?
	Q11: How is the usual teaching method for that particular subject?
	Q12: What is the need for that particular topic to be in a digital form/ application?

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i) Discussion of findings

Learning Material

The teachers in the study knew that the multimedia approach is the most effective learning material in teaching mathematics. Based on Q1, R1 uses the courseware available on the computer at the school's laboratory to aid their learning for a better understanding of the concept. However, the teacher said they rarely use the handheld devices such as a tablet as there is no specific application for the LV learners to explore. So, the teacher tends to utilize the already installed courseware named Math Flash (refer to Figure 1.1) in the computers. According to the teacher, learning only from the textbook make the LV learners harder to understand due to the size of the fonts being too small and the lack of interactive elements to attract them to understand. Contrary to R2, the school never had the courseware as per R1. However, R2 still uses digital learning materials such as Youtube or websites as for the digital learning material. The students need to adapt to the general educational videos and websites in learning mathematics.

Based on Q2 and Q3, both R1 and R2 stated that they utilize mobile device such as tablets during the lesson, but most of the applications are limited to general students only. There are no other choices instead of to open the application using a tablet and enlarge or brighten the screen display.

Based on Q4 and Q5, R1 refers to the courseware where the courseware is too basic (refer to Figure 2). The courseware does not contain any multimedia elements of audio, graphics, animation, and video. The students need the

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teacher to aid them to operate the courseware. However, R2 refers to the most frequent application they use which is Youtube which contains all the multimedia elements, however, the elements are not suitable for LV learners.

Availability of mobile application

R1 responded to Q6 as the available courseware installed in the school's laboratory is from an unidentified source and was analysed by the researcher based on other special needs schools, there is no courseware as mentioned. There is no standardized courseware or applications from the Ministry of Education for the special needs schools in Malaysia. R2 has confirmed their school also does not have the courseware as well.

Hence, it was found out that all the learning materials used are the same for the general students including textbooks as there is no standardization from the Ministry of Education in the development of a mathematics model for LV learners. R2 added there is also not enough assistive aid for low vision that has been supplying to the school. The assistive aids supply also is very limited and only selected special needs schools well-equipped assistive technology.

In addition, if the assistive aid broken it has no replacement and the student need to adapt their learning without any AT. For example, if the CCTV for enlargement of the text is broken the student must adapt learning without it. Sometimes they borrow from the other school.

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R1 and R2 both responded to Q7 that almost all the available applications are not catering to the needs of LV learners in learning mathematics. They are not familiar with other applications available in the market mostly for general students. Even though sometimes they use such as educational videos on Youtube for learning, the LV learners need to adapt to the content provided as most of them are designed for general students.

Needs of mobile application

R1 stated that the motivation level when the LV interacts with the courseware, or any mobile application is different from the conventional teaching in the class. They are performing better when learning using the courseware. R2 stated that when using Youtube as learning material the student need to repeat the video multiple times the student to understand the concept.

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However, learning through the means of multimedia is the best choice for making the student understandable mathematical concepts. Therefore, both R1 and R2 highly suggested and were delighted in recommending a proper mobile application that was specifically designed for LV learners for their response for Q8.

Subject Requirement

R1 responded to Q9 as the most critical subject is multiplication and division which requires the LV learners to visualize the object to perform the calculation, whereas the available courseware only acts as enlarged digits in the digital form of courseware. R2 responded to Q9 with the same subject and added fractions also having the same difficulty for the LV learners to understand. However, both respondents agreed on the subtopics of multiplication and division as they involve reverse calculation.

According to R1 based on Q10 multiplication and division requires LV learners to look at the object or visualize the objects to perform the calculation. They need to have an attractive visual to ease them to perform a calculation based on grouping the objects. R2 responded as LV learners are having problems with the same topic as well. R2 stated that even though they have played the educational videos on that particular topic the LV learners need to take some time to adapt to the learning content and understand the content itself.

Both R1 and R2 will opt for concrete learning material or hands-on learning material such as cups, and paper plates to explain the concept more clearly. Digital learning provides a limited understanding of the concept as poor instructional content and elements are implemented in the applications.

R1 responded to Q12 as there is a need to incorporate a new mobile application that implemented all the specific designs to evoke positive reactions for the LV learners in learning mathematics. R2 responded to Q12 as the textbook

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separated the topic by topic however the operation is still the same. For example, multiplication in time is the same as multiplication in money. However, the topic is separated from the textbook. It is hoped that a mobile application with the usage of multimedia elements such as using multiple types of graphics such as clock and money notes in one place can elicit the understanding of LV learners in performing the multiplication and division operation.

This study shows that there is an urge needs the assistive mobile application for LV learners in learning Mathematics.

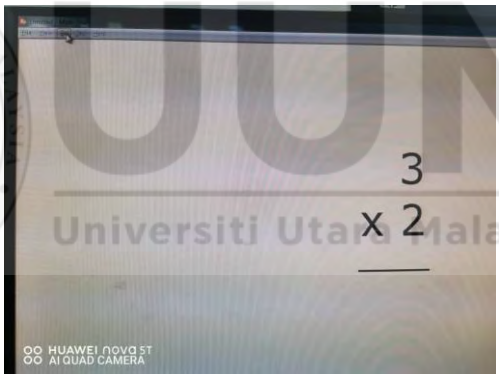

Figure 1.1 Math Flash Courseware

1.5.2 Preliminary Study II

Studies on mobile applications need to be accelerated to comprehend the needs and requirements of LV users. Therefore, it is important to analyse LV learners' background, health condition, and interaction LV towards AT in relation to learning through the mobile application. A series of semi-structured interviews have been carried out with the expert in LV about the LV background and the AT used for the LV. The respondent addressed R3 is a vision rehabilitation optometrist who has

experience managing LV communities in the United Kingdom and is currently a lecturer at one of the universities in Malaysia. The session between this study and the content expert e was conducted one to one through virtual interviews. In the interview, 6 questions as listed in Table 1.5 were asked in a semi-structured format.

Table 1.5

List of Semi-Structured Questions

Scope	Questions
Low Vision Background	Q1: What is the definition of low vision?
Health Condition	Q2: What is the specific term for a type of low vision which has blurry vision despite one that has a specific range of sight such as tunnel vision (called glaucoma)?
Interaction with the Assistive Technology	Q3: Based on your experience in managing the LV community in the UK, how is AT applied there?
	Q4: Does tablet/ mobile application compatible with LV learners?
	Q5: Between visual and audio, which is more tattractive to the LV?
Future perceptions	Q6: What can you say about the future of LV learners? What can guarantee the brighter future of this community in a Malaysian setting?

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i) Discussion of findings

Background of Low Vision

R3 responds to Q1 by stating the general definition of low vision from the World Health Organisation. Then R3 further narrows the definition based on the Malaysia setting.

> *...Low vision is a condition where an individual has visual acuity is less than 6/18 up to 3/60 or when the visual field is less than 20 degrees in the better eye despite the best possible corrections* (Welfare Department of Malaysia, 2021)

However, R3 stated that based on the definition, there is a 'thing' left in the definition which is the term 'functional' low vision. R3 stated despite having LV, if the patient can do their daily activities for example cooking, and walking. The patient considered has the potential for rehabilitation or intervention. For example, interacting with the application devices or magnifying glass (e.g assistive devices).

However, Keeffe (1995) mentions in his book Assessment of Low Vision in Developing Countries that functional vision refers to the use of the small amount of useful vision for a particular purpose such as to recognize a person close up or to avoid objects.

Health Condition

R3 responded to Q2 as it is plausible to choose the condition of 'Overall blurry' as the target user as it is the most common disease occurring to LV, especially for children. R3 coined the term 'Overall blurry of vision' which all types of LV can cause overall blurry.

Interaction with the Assistive Technology

R3 answered the Q3 by comparing Malaysia setting with the UK setting of the LV community. Both countries have the similar schools that are provided specifically for visually impaired students. However, in terms of technology, of course, the technology in the UK is more advanced according to the high charge of tax and awareness about the technology for the visually impaired.

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R3 respond to Q4 based on the technology engaged with the rehabilitation for LV. R3 stated it is best to use the tablet as the medium for learning in terms of its portability. While R3 stated the answer for Q5 was that is best to combine both elements LV visual as people with low vision usually can hear better. So, it is best to combine both audio and visual elements.

Future Perceptions

R3 responds to Q6 by stating that the future for people with LV is bright if they try to engage and explore more with the use of technology despite using normal devices such as magnifying glasses. In addition, there is a need to improve the teachers' skills in teaching and learning for LV learners by using technology in the classroom.

1.6 Problem Statement

At this early point, the results of the preliminary investigation have demonstrated the importance of the research problem for this study is relevant. Preliminary studies and existing literature have shown that there is a need for this research because there is now a dearth of mobile applications tailored to students with low vision. Table 1.6 serves to outline the issues based on the target user's background and learning materials for LV learners, availability of the mobile application, the needs of the mobile application, and subject requirements.

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Table 1.6

Summarize The Problems

Scope	Problem
Low Vision as a target User	- Lack of technology used in an education setting for LV learners - Limited interaction with a mobile application for learning purposes due to eyesight problems.
Learning material	- Using general digital learning material such as Youtube. - Limited exposure to the specific application for LV - Engage with all the multimedia elements with limited control over the learning material.
Availability of mobile application	- Unstandardised courseware supply for different special needs schools. - Limited market availability of the mobile application for LV.
Needs of mobile application	- Existing application is too general. - Too boring conventional method of teaching. LV learners were more motivated by technology used in teaching and learning. - Shows positive reaction towards the use of courseware or mobile application despite conventional teaching in class.
Subject requirement	- Most of the topics are critical such as basic operations that involve multiplication and division. - Mathematics requires more visual- attention as it involves symbols. - Uses conventional teaching method with hands-on the material to visualize the concept.

Based on Table 1.6 shows the issues that lead to the need for educational mobile applications to motivate users (Kalogiannakis and Papadakis, 2019) to engage them to learn mathematics.

1.7 Research Questions

Based on the identified problems, the following research questions are put forward:

i. How to construct the affective design principles for LV learners?

ii. How to validate the affective design principles for LV learners?

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1.8 Research Objectives

The main aim of this study is to propose a set of design principles of affective mobile mathematics for LV learners which namely as AMM4LV learners, to support LV learners in mathematics through the mobile application. Therefore, to achieve the main goal, the following specific objectives must be formed:

i. To construct the affective design principles through comparative analysis and a user-centered design approach.
ii. To validate the affective design principles through prototyping, expert review, and user experience testing.

1.9 Significance of the Study

The aim of this study is to develop a mobile application in mathematics subject. The development of the mobile application has taken the mean of technology with affective four dimensional design principles into consideration as a guideline for the developers, and creative industry practitioners to provide more apps for LV learners.

In addition this study also aims to fulfil the needs of special needs student in accessing multimedia content in their learning in line with the objective of Special Needs Department to provide adequate and up to date teaching and learning materials (Special Needs Department, 2023).

Moreover, the developed prototype for LV learners as an additional teaching tool to assist teachers to teach LV, particularly mathematics to evoke positive learning experience in terms of emotion, thought, feeling, and action. The importance of practicing technology in the classroom is that there has two-way interaction by the means of technology in education, thus guide the students more efficiently in

performing student-centred learning despite the one-way communication of teacher-centred in the classroom.

1.10 Research Gap

Based on the problem as discussed in the previous section, the following research gaps are extracted:

i) Affective four dimensional design principles of mobile application specifically for LV learners is lacking and insufficiently explored.
ii) Most of the existing mobile content application lack accessibility to LV learners particularly in mathematics subject.

1.11 Scope of Study

This study is carried out to construct a set of Affective Four Dimensional Design Principles of mathematics mobile applications for LV learners. Hence, this study focuses on:

- Construction of set of affective four dimensional design principles for mobile mathematics application.
- Development of mathematics mobile application specific for LV learners.
- LV learners as the target user. Focused on primary school of standard two to six.
- Mathematics subject as a common critical subject for LV learners.

1.12 Theoretical and Research Framework

This study is carried out based on theories and concepts from the fields of AT and educational technologies with a focus on mobile applications. The theoretical framework of this study is presented in Figure 1.2 based on the five phases outlined in Chapter 3. Both the problem and the scope of the research were determined through preliminary research and elicitation from the existing literature. The affective four dimensional design principles were determined through a content analysis and literature review focusing on relevant concepts and theories. In addition, a comparative analysis of the existing models (mobile applications) has been performed to corroborate the research gap and identify their accessibility component that relates to the affective component. Based on data presented in Figure 1.2 collected in Phase 2, a set of affective four dimensional design principles were constructed. The proposed design principles has confirmed its viability through prototyping and expert review. Lastly, the conclusion provides an analysis of the findings by answering the research questions and research objectives.

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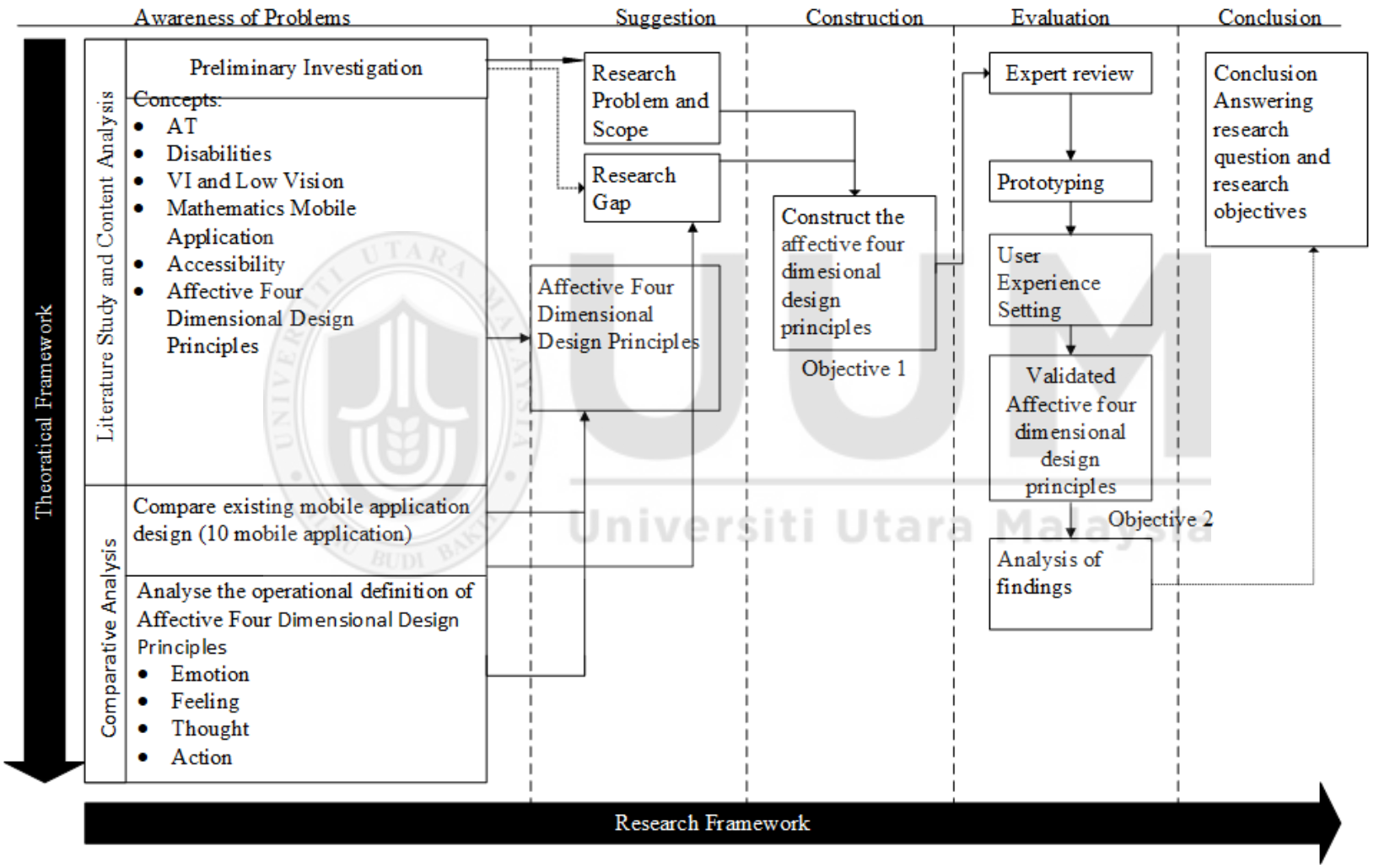

Figure 1.2 Theoretical Framework

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1.13 Definitions of terms

This study incorporates various terms that may also comprise other studies. However, they may convey slightly different meanings. Hence, the terms used in this study are defined in the following subsection:

1.13.1 Operational definitions

i. Mobile Human Mobile Computer Interaction – the daily interaction between humans and mobile computer systems and applications (Love, 2005). In this study, mobile device acts as platform for the LV learners to interact with the content through the mobile application named AMM4LV.

ii. Assistive Technology - Assistive Technology helps disabled people overcome weaknesses (Hermawati, & Pieri, 2019). In this study, assistive mobile application designed for LV learners to learn subject in school.

iii. Affective Design – Systematic approach to the analysis of customers' reaction (Jiao et al,. 2006). In this study, a set of affective four dimensional design principles are used in the mobile application for LV learners.

iv. Mobile application - Computer programme or software application run on a mobile phone, tablet, or watch software (Mamolo, 2022). In this study, the AMM4LV installed in the tablet during the user experience testing.

v. User- Centred Design Approach - Process of ensuring design fulfils users' demands and abilities (Norman, 2013). In this study, UCD approach have been utilised to achieve the main objectives of this study.

vi – User Experience - A person's thoughts and feelings about a product, system, or service (ISO, 2010). User experience testing were conducted to validate the affective four dimensional design principles.

vii. Low Vision - Visual acuity of less than 6/18 but equal to or better than 3/60, or vision field loss to less than 20°, in the better eye with the best available correction (WHO, 2021). In this study, most of the subjects are blurry vision. Totally blind subject is excluded from the list.

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1.14 Summary

This chapter explains the background of this study which includes the motivation for carrying out the research, problem statement, preliminary study, research questions, research objectives, the significance of the study, scope of study, and definition of terms.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter examines significant subjects linked to this study to illustrating the theoretical underpinnings of the study. Initially, it provides an overview of AT, including a definition of AT as well as the several types of AT that are currently in use around the world. Following that, an overview of disabilities is provided to inform readers about the current state of PWDs in Malaysia, as well as the types of disabilities that are discussed in this study. Next, a discussion on the existing educational mobile application is presented, with an emphasis on the adoption of mobile applications through the learning environment. An explanation of accessibility guidelines that are relevant to the study that contains affective design, which is also known as emotional design, is also included in the document. Finally, a review of affective four dimensional design principles is discussed.

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2.2 Assistive Technology

The lives of people with physical or perceptual disabilities are often filled with different objects that promote daily activities and are generally referred to as assistive technologies (AT). AT has been an incredible force for equality between people with disabilities. A wide spectrum of people with visual disabilities has been successfully integrated into education, employment, and general society using the appropriate AT. Throughout the advancement of technology in life, many of these improvements have been put into practice by assistive technology. Even though, regular people are also developing self-reliance on technology as a part of a necessity to advance their day-

to-day responsibilities in this new age of technology. Because of this, people with disabilities have also been influenced by the quick change caused by advances in technology. This is where assistive technology comes in handy to them. Researchers, organizations, and society describe AT according to their preferences and perspectives. AT is hardware or software designed to help disabled persons do daily tasks. This research defines AT as any hardware or software designed for people with impairments.

Peta (2018), Talib et al. (2019), Zander (2020), and Palmdorf (2021) describe assistive technology (AT) similarly to the World Health Organization (WHO) where AT is mostly devices and services. Assistive technologies are "assistive devices and technologies that are to maintain or improve an individual's functionality and independence to facilitate participation and to enhance overall well-being," (WHO, 2018).

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Additionally, Voorhies & Dickson (2018), Shipe (2019), Edge-Savage & Marotta (2019), and Bruno et al. (2020) define AT devices as follows: "Any product, equipment, or product system, whether purchased commercially outside the shelves, changed, or customized, used to increase, maintain, or enhance the functional ability of children with disabilities." According to the Individuals with Disabilities, Education Act (IDEA, 2004) an AT service can be defined as any program that specifically assists a child with a disability in the collection, acquisition, and use of assistive technology equipment. It can be divided into two categories, which are high-tech and low-tech AT devices. The higher the level of technology, the greater the level of complexity, and the greater the price. In the case of adaptive equipment, voice recognition software, or

word prediction software, they also demand user education or instructions (Johnston & Watson, 2007). Low-tech equipment, on the other hand, is reasonably priced because it is less expensive than high-tech equipment, can be assembled quickly, and requires less training. In addition, low-tech gadgets include, talking watches and pencil grips and other low-tech gadgets such as eyeglasses and ear plugs to reduce distracting sounds and noise (Johnston, 2017). AT is intended to aid and support people who are experiencing problems or disabilities. As a special educator, the researcher is concerned about the well-being of students, particularly those who have impairments. Students with disabilities must be able to participate fully in the classroom in a non-discriminatory educational environment.

Nsofor and Bello (2015) state that AT range from low-tech to high-tech equipment. Usually, low-tech technologies are popular and cost-effective devices and instruments designed or modified to aid in various difficulty areas. They have simple pencil grips, magnificent eyeglasses, and large-print cardholders. The findings of prior research in the special education ecosystem, which was similar to the findings of the low-tech study, revealed that these innovations could not completely support student-centered learning. High-tech learning and teaching must be integrated into the classroom environment as well. High-tech systems are provided by advanced electrical and computerized technologies (high-tech). In the 21st century, the physically challenged need high-tech assistant technical equipment to compete with their counterpart worldwide. Every technical level of supporting technological resources is different in terms of quality and effectiveness. Adjusted to no-tech to high-tech and the rapid growth of digital media learning resources, teachers and students of assistive

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technologies will be able to engage with the visualization and viewing of non-textual information in Pisha & Coyne (2017).

The primary aim of assistive technology is to preserve or enhance its functioning and thus to improve well-being through independence, dignity, and social involvement.

2.2.1 The Types of AT

Based on the definition as described in the previous section, the categories of assistive technology based on Table 2.1 include:

Table 2.1

Categories of Assistive Technology

Types of AT	Description
Augmentative Communication AT	A variety of devices that help people with specific communication needs augment, supplement, or substitute their complex communication needs (Ascari et al., 2018).
Computer Access AT	Briefly discuss in the next subsection
Daily Living AT	Everyday living aids, self-care equipment, and basic assistive technologies facilitate daily functioning activities (Hammel, 2014)
Education and Learning AT	Two types of Education and Learning AT based on Malaysia educational setting: **Optical aids**: magnifying and enlarging the retinal image for example glass lens and telescope. **Non-optical aids**: increase visual resolution for example magnification of materials (Monteiro et al., 2014)
Environmental AT	Environmental Control AT can be divided into two categories: **Electronic aids**: such as switches, environmental control units and modified devices used by people with physical disabilities to enhance their independence in all types of environments (Peraković et al., 2018). **Non-electronic aids**: Person with physical or functional disabilities may use such a device to strengthen their ability to control their environment, increase their independence, and improve their quality of life

Ergonomic AT	"A common factor in all manufacturing disciplines share an emphasis in ergonomics, which can be perceived as the mortar that binds the manufacturing structure into a holistic system (Grossmith & Chambers, 1998).
Sensory AT (Vision or Hearing Impaired)	Magnifiers, Braille and speech output devices, extra-large print screens, visual alerting systems, and telecommunication devices. This includes assistive listening devices, hearing aids, personal amplification systems, audio or FM loop systems, FM amplification systems, TV amplifiers, TV decoders, visual sending a signal and alarm systems, tactile alarm systems, telephony and accessories, text telephones, Telecommunications Device for the Deaf (TDD), and TV decoders and adapted phones (Mills, 2010)
Mobility AT	Products that help mobility-impaired people navigate and travel independently (Borg et al., 2012)
Prosthetics and Orthotics	Replacement of a patient's missing or defective body components with an artificial limb or other orthotic device (WHO, 2017)
Recreation and Leisure AT	This group of products includes modified sports, and some common subcategories (Verdonck et al., 2023) • Sports Aids • Toys and Games • Travel Aids
Seating and Positioning AT	Products that help mobility-impaired people maintain an upright posture, provide trunk/head support, and reduce skin pressure (Pontes et al., 2021)
Services	Any service that directly aids an individual with a disability in the selection, procurement, or use of an assistive technology device (WHO, 2023)

i) Computer Access AT

Computer Access ATs can come in various ways, such as running on a desktop computer or a mobile phone or tablet (Dethlefs et al., 2017) According to Bhavna et al. (2021) in their overall results the survey shows that computer assistive technology is viewed as an important tool for users to achieve their educational, job, and personal goals. This shows that computer-based ATs have a broad range of modifications that allow PWDs to access data from anywhere and at any time. Among the committed international companies to promoting accessibility to disabled user in their products is

Apple Incorporated. They are concern with the needs of PWDs have been implemented in their latest operating system (iOS14) with a standard feature to support users' vision, physical and motor, hearing, and learning needs. The examples of features provided are described in Table 2.2.

Table 2.2

Mobile Accessibilities Feature in The Apple Operating System

Target User	Features	Function
Vision	VoiceOver	Audible descriptions on the screen
	Zoom	Magnify the entire or part of the screen
	Magnifier	Acts as a magnifying glass to zoom
	Display & Text Size	Customizable size of the screen
	Motion	Control the movement of some elements on the screen to reduce the motion sensitivity
	Spoken Content	speaks selected text or the entire screen and provide correction and suggestion as user type.

According to Table 2.2, Apple Incorporated provides enhancement of accessibilities features in their latest operating system iOS14 in providing a better user experience with their products. Hence, the built-in features are one of the most advantageous features that can allow their range of products such as iPad as AT devices, and make it easier for students with disabilities to access and use their devices. In a wide variety of areas, such as vision, hearing, and physical and motor skills, the features will enable them to improve in accessible technology development.

Further, Android also offers accessibilities feature which is designed with additional accessibilities for disabilities. Android accessibility features allow users to customize their devices by modifying accessibility settings or applications. This enables individuals with a range of disabilities to improve their ability to access and interact

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with web pages and apps, such as visual, hearing, physical, or speech impairments. The examples of features are categorized as described in Table 2.3.

Table 2.3

Mobile Accessibilities Feature in The Android Operating System

Type of support features	Features	Function
Vision	TalkTalk	Fully interact with the screen.
	Lookout	Using the camera to identify the nearby object.

In conclusion, based on both Table 2.2 and Table 2.3 above, both the Apple OS and the Android OS offer an "Accessibility" screen where these functions can be enabled and customized to the user's preferences. Zoom, voice command, and several audio feedback options are among the features described in both tables. The basic accessibility features on both Apple and Android products have been maintained and upgraded with each software update.

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2.3 Disabilities

About 1 billion individuals, mostly those with disabilities, live in conditions that significantly restrict their quality of life. According to World Health Organisation (WHO,2020), over 15% of the world's population experiences severe challenges in functioning, with up to 3.8% of the population, aged 15 and up receiving regular healthcare services. As our populations grow older, and the numbers of people with chronic health conditions increase, the number of people living with a disability is increasing.

In Malaysia, 578,591 people suffer from a disability, and they represent 1.8% of the country's population in 2020. Referring to Figure 2 the number of new registrations of PWDs dramatically increases from 409,269 to 578,591 from 2016 to 2020, although the number of new registrations as PWDs slightly decreases in 2019.

However, the number of persons registered as PWDs substantially increases from 488,948 to 578,591 from 2019 to 2020. In addition, there is the lowest number of persons registered as PWDs in 2016, whereas the highest number of persons recorded (578,591) in 2020 during the registration as PWDs (Department of Statistics Malaysia, 2016-2020). In summary, the number of new registrations as PWDs implies essential information although the number fluctuates yearly. The number of PWDs greatly increases by adding up the total number of new registrations from the preceding year. Figure 2.1 shows the registered PWDs in Malaysia for over five years (2016 to 2020).

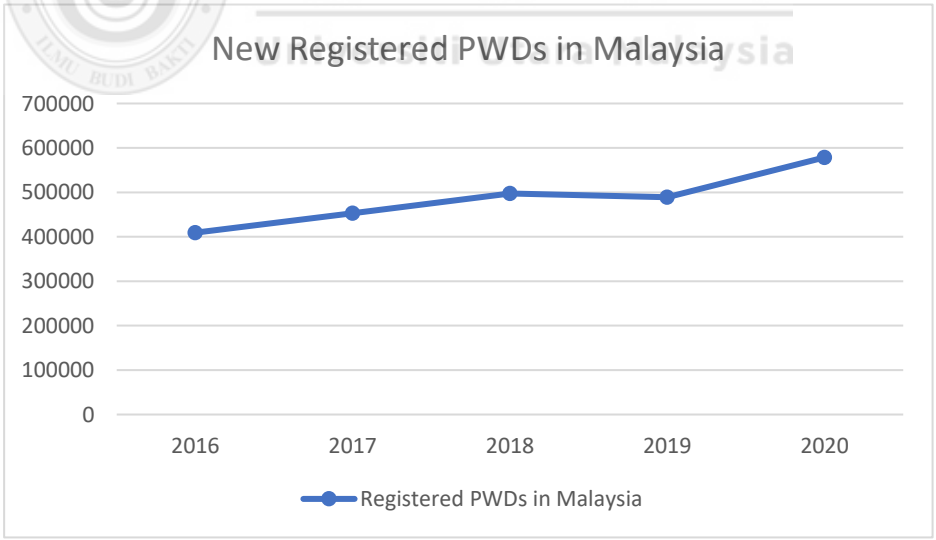

Figure 2.1 Registered PWDs in Malaysia 2016-2020

2.3.1 Types of Disabilities

In accordance with the Persons with Disabilities Act 2008 (PWD), "PWD, denotes persons who are afflicted with long-term physical, mental, intellectual, or sensory

disabilities, which hinder them from fully and effectively participating in society when faced with challenges. According to Social Welfare Department (2023), there are seven categories of the PWDs, and they are identified in Table 2.4 as follows:

Table 2.4

Types of Disabilities

Types of Disabilities	Description
Visual Impairment	Discussed briefly in the next section
Hearing Loss	Cannot hear in both ears with or without hearing aids.
Learning Disability	Brain intelligence issues that defy biological age. Global development, Down Syndrome, and intellectual difficulties qualify them. Autism, ADHD, Dyslexia, Dyscalculia, and Dysgraphia are also included in this category.
Physical Disability	Physical disability, including hemiplegia, paraplegia, and muscle weakness, prevents people from doing basic tasks including self-care, movement, and body position adjustments.
Mental Disability	A severe mental illness condition that has been treated or has been identified for at least two (2) years by a psychiatrist. Despite psychiatric treatment, they cannot function in self-care or social relationships. Schizophrenia, Paranoid, and Mood Disorders are mental illnesses.
Speech Impairment	Due to communication impairment, cannot talk and cannot be understood. This condition will remain or will not heal.
Multiple Disabilities	Has several disabilities and cannot be categorized in categories one to six. But, "Deaf-blindness" is not defined in this definition.

2.4 Visual Impairments (VI)

Visual impairments may include low vision and blindness, and the two terms are defined as any degree of visual impairment that impacts someone's ability to navigate in their daily life as suggested by the Department of Veterans Affairs (2002), Seyama (2010), and Sapp (2010).

In classifying the definition of the terms low vision and blindness, the low vision describes a range of visual impairments, some of which are more moderate than total

blindness, but that nonetheless influence a person's ability to carry out everyday activities to some degree (Sapp & Hatlen, 2010). People with low vision may require the use of tools and procedures to expand their capacity to use their limited vision, or they may need to use nonvisual means for completing activities. However, functional low vision is another important term that needs to be defined. This is described as "VA less than 6/18 up to the perception of light, with treatment and the best possible refractive correction, or visual field less than 10 degrees from the point of fixation" (Suomi & Sachdeva, 2016). This is an important definition for the evaluation because a person with this vision may benefit from low-vision devices and services. This person needs to be encouraged and taught to get the most out of what vision they still have, often with the help of devices and changes to their lifestyle.

Whereas blindness refers to the total absence of vision, it is more commonly used to refer to severe visual impairments that cause the usage of nonvisual sensory information to be mandatory. In simple words, blind refers to no light perception at all; low vision refers to permanently reduced vision that cannot, be corrected with regular glasses, contact lenses, or surgery (Othman et al., 2020).

According to WHO (2021), almost 2.2 billion individuals suffer from some form of visual impairment. Whereas visual impairment (VI) is referred to as a limited range of sight and focus and VI is hard to be corrected by spectacles and its severities range from low vision to complete blindness (Seyama, 2010).

However, there are few causes have been identified for VI. Based on the study was carried out to outline the contribution of causes of blindness and vision impairment

globally over the trend of 30 years from 1990 to 2020 (Lancet Global Health, 2020). Ranging from the highest to the least cause where the highest cause for VI is cataract (15.2 million cases) followed by glaucoma (3.6 million cases), undercorrected refractive error (2.3 million cases), age-related macular degeneration (1.8 million cases), and diabetic retinopathy (0.86 million cases). Further, the cause of VI are as listed in Table 2.5.

Table 2.5

Cause of Vision Impairment

Cause	Description
Cataract	A cataract is a clouding of the lens of the eye that can often reduce or blur the eyesight (WHO, 2021).
Glaucoma	Glaucoma refers to a set of disorders that are similar to diseases. Long-term eyesight loss may go unnoticed. Patients will have headaches, blurred vision, and eye pain (NEI, 2020).
Undercorrected Refractive Error	Refractive problems may lead to blurred vision and visual impairment (Dhaliwal & Hassanlou, 2015).
Age-related Macular Degeneration	AMD is a progressive eye disease. The person over 60 loses their sight to glaucoma. Retinal degeneration occurs when the retina's macula wears away. It is often described as age-related macular degeneration as this condition arises when the person becomes older (Bird, 2010)
Diabetic Retinopathy	Diabetes causes retinal damage. Eye blood vessels leak or clog, damaging the retina. Diabetic macular edema, which increases retinal density, usually causes vision impairment (NEI, 2019).

In addition, this study classifies the above categories in Table 2.6 based on the current version of the International Classification of Diseases 11 [ICD-11] (2018) which has been revised and formulated under the WHO (2021) that classifies vision impairment into two groups, distance and near presenting vision impairment. The distance vision impairment categories were mild (defined as visual acuity of <6/12 and $\geq 6/18$), moderate (visual of <6/18 and $\geq 6/60$), severe (visual of <6/60 and $\geq 3/60$), and blindness (visual acuity of <3/60).

Table 2.6

Level of Vision impairment

Level of vision impairment	Visual acuity scale		
	6m	20ft	Decimal
Mild	<6/12 but ≥ 6/18	<20/40 but ≥ 20/70	<0.5 but ≥ 0.3
Moderate	<6/18 but ≥ 6/60	<20/70 but ≥ 20/200	<0.3 but ≥ 0.1
Severe	<6/60 but ≥ 3/60	<20/200 but ≥ 20/400	<0.1 but ≥ 0.05
Blindness	<3/60	<20/400	<0.05

Based on the reference to the range in Table 2.6, a child with visual acuity of less than or equal to 0.3 but better than 0.5 is categorized as mild or partially sight where the children can discern symbols at 6 meters of 20 feet with the visual field loss of 20 degrees or less (WHO, 2018). Moderate VI (WHO, 2018) means that a visual acuity of less than or equal to 0.1 but better than 0.3 is categorized as moderate or low vision. Meanwhile, the visual acuity for severe impairment or legally blind is less than 0.05 but better than 0.1 corresponding to their visual field loss of 20 degrees or less. Whereas visual acuity for totally blind with a visual field of fewer than 10 degrees or less is considered to not have any light perception in their sight which cause blindness.

Figure 2.2 Types of Low Vision

On the other hand, the above Figure 2.2, from left shows the comparison between normal vision, a person's vision with cataract, central field loss caused by age-related macular degeneration, glaucoma with certain field loss at the edges of sight, reduction of visual field that caused by retinitis pigmentosa and certain field loss that caused by retinopathies diabetes.

As a result, it has been agreed that the subjects of this study, which conducted in a manner of the Malaysian context, would be children who do not have any visual field disturbances but have poor vision. The conclusion of this is that they can differentiate visual detail while experiencing no difficulties with the field of vision. As a result, focusing on LV learners is the most rational option because:

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i) As previously stated, and explained in the previous section and Chapter 1, the use of magnifying glasses, CCTV, or other AT devices in conjunction with learning materials is restricted to the classroom setting solely.

ii) In preliminary research findings, it has been discovered that interactive content containing multimedia features such as graphic and textual elements, audio, and animations is more appropriate for meeting the needs of LV learners.

iii) Lack of assistive mobile application for LV learners in mathematics subjects.

iv) As a recommendation from the content experts (i.e., VI teachers) to make this study beneficial to them in the future.

2.5 Affective Design Principles

The term “affect” has been long discussed and was first introduced by Rosalind W. Picard about two decades ago as a subfield of Human-Computer interaction (HCI), affective computing (Picard, 1997). Picard (1997) believes in the computer’s potential in recognising, understanding, expressing, and reproducing human emotions. As both of computer and user the interaction, the device can detect and respond to its user’s emotions (Picard, 2000). In addition, the affective design principle has been widely adopted in various fields such as fashion (Vélez-Granda, 2018; Li et al., 2019), education (Park & Lim, 2019), and health (Coetzer, 2017). The goal of affective design principles is to create and deliver affective interfaces (Cyr, 2015). This is due to the application may elicit certain feelings from the user, providing him or her with a pleasurable experience when interacting with the interfaces (Coetzer, 2017). As a result, the user may be able to achieve both his or her intended goals as well as the goals for which the application was originally designed. This argues that it is vital to identify the user interface design and its effect on a user, especially for LV learners. The study of the user interface design in terms of affective design could be identified and classified as providing an emotional response from a specific design to a specific user (Bødker et al., 2003).

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2.6 Affective Four Dimensional Design Principles

In response to the affective four Dimensional Design Principles, the researcher proposed to present the four dimensional components which are emotion, feeling, thought, and action as a distinct affective design principle in developing a mobile application for LV learners. Table 2.7 summarised the proposed components and a set of items derived from the operational definition of the component. All the items will

be discussed in the next subsections to identify a set of affective four dimensional design principles

Table 2.7

Proposed Components of Affective Four Dimensional Principles

Four Dimensional Components	Items
Emotion Associates with the positive events which relate to the positive memory and motivation of the LV learners.	i) Memorable ii) Motivational
Feelings Associates with the positive emotional state which refers to the interest and happiness of the LV learners.	i) Interest ii) Happiness
Thought Associates with the cognitive ability which produces positive perception and mind stat of the LV learners.	i) Positive perception ii) Positive mind state
Action Associates with the positive emotion, feeling, and thought that can guide positive action or behavior through the navigation and interaction of LV learners towards the LV mobile application.	i) Navigation ii) Interaction

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- ***Emotion***

i) Memorable

Firstly, in response to the emotion term, "affective" term is commonly related to or acts as the synonym term for "emotional" (Politou et al., 2017). In addition, the term "emotion" and "affect" have often been used interchangeably, however, they do not share the same definition (Nacke, 2011). According to Norman (2004), "affect is a general term for the judgmental system, whether conscious or subconscious" such as when the users are experiencing an uncomfortable feeling without knowing the reason, this is called affect. Whereas emotion is the conscious experience of affect (Norman, 2004). Thus, emotion shows a noticeable cause that arises and diminishes instantly (Jeon, 2017).

Mustafa et al., (2008) added, emotion is a temporary psychological, physiological (e.g., heart pounding), and behavioural response to thoughts, events, and social activities. Furthermore, Chakrabarti and Gupta (2007) defined emotion as a feeling or reaction as a felt tendency or reaction toward anything, such as people, objects, ideas, or events.

In addition, emotion is also related to memory as defined by Derryberry and Tucker (1994) where emotion effect cognition on many levels such as memory, attention, and perception. Isen et. al (1987) also added emotions have also been found to provide effective retrieval cues for long-term memory.

Furthermore, emotions influence how people pay attention and how they remember things as emotion is so tightly associated with memory (Coetzer, 2017). According to Walter (2011) if they were unable to recall unpleasant or positive experiences, they

would be unable to protect themselves from experiencing negative events again or to consciously replicate positive events (Walter, 2011). Therefore, a study by Ahmetovic et al. (2021) was implementing consistency in design by locating the interactive elements such as buttons in the same position on all screens. Another study by Pinasthika (2020) also aims in providing a memorable experience in delivering understanding to the user. The study suppresses the visual consistency of graphics used for buttons, icons, menus, and content according to the users.

The user is not required to memorize the steps every time they utilize it. After the interaction, the user will remember and avoid an error. The research incorporates a memorable design based on usability goals into mobile application design (Krug, 2014). Useful, learnable, memorable, effective, efficient, desirable, and delightful are the usability goals. Consequently, the interface should highlight previously viewed information to help a child remember earlier activities like navigating the application (Mak & Nathan, 2017).

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Consequently, a memorable design helps serve multimedia content to LV learners in this study. "Meaningful" experiences in people's long-term memory are from memorable experiences (Wan, 2020). Meaningful experiences engage and build character strengths, knowledge, and skills (Elkington & Stebbins, 2014).

This is because mathematics usually represented as a visual material such as various types of symbols often affects their performance in performing arithmetic calculations (Daroni et al., 2018). Due to their limited eyesight, learning mathematics would be very difficult for them to memorize and categorize all the symbols. To enhance their

performance in learning mathematics, providing a consistent design in a mobile application will be beneficial for LV learners. As a result, the LV learners will have a meaningful experience in learning and retain the knowledge obtained from the mobile application.

Hence, in this study, developing a mathematics mobile application by incorporating emotion as part of the affective design retains a memorable experience in learning and reduces to reattempt the mistake in performing mathematical calculations in the future.

ii) Motivational

In addition, Katai (2020) in his study also revealed that positive emotion also contributes to students' motivation to learning. Porcher-Sala (2019) added a lack of stimulus and motivation are also one of the factors that affect students' understanding of mathematics. As previously stated by Valle et. al (2011), motivation is crucial in learning and acts as a fundamental component of all measures to achieve active learning. Based on Keller (2010) Emotional Theory, defined motivational design as the systemic process of "arranging resources and procedures to bring about changes in people's motivation".

In addition, motivational design elicits a positive engagement between the user and the system or their engagement in completing the task they are assigned (Hamari et al., 2018). In a study, the use of 'happy' colour enhanced the motivational levels of primary school in learning mathematics (Ng & Chiu, 2017). The study resulted that the group with additional emotional design had the highest motivation level compared to the control group. However, in another study of the development of the mobile application

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for low vision, the most preferable background and foreground colour is black text on a white background rather than white text on a black background (Ceccarini & Prandi, 2019).

Thus, delivering multimedia content that caters to the context of low vision required a suitable selection of colours. Hence, emotion is one of the affective components to induce a memorable and motivational design to assist LV learners in learning mathematics subject.

- ***Feelings***

i) Interest

Feelings are the conscious mental representation and interpretation of that bodily response (Damasio, 1994, 2001). While emotion is viewed as an "overall feeling" that is stimulated by various stimuli including both external and internal stimuli. The stimulus is "context, experience, recent experiences, personality, affect, and the net cognitive interpretation of these influences". Yet, emotion is described as the collection of feelings at that moment (Nasrun, 2021). Hence, feelings are known to follow emotion evolutionarily and experientially (Jeon, 2017).

Emotions are subjectively experienced states, and our responses vary according to our background, prior experience, mental and physical state, and other individual factors (Castelfranchi, 2000). Thus, a study indicates that emotional states are classified into three categories which are positive, neutral, and negative (Tomkins, 1963). Positive emotional states are interest and happiness, neutral is surprised, and negative emotional states are sadness, disgust, anger, fear, contempt, and shame.

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Hence, in this study researcher focuses on the positive emotional state which interest and happiness. Emotional states affect learners' interest in approaching or avoiding the subject or instructor, according to Mehrabian (1972). People will be interested in things and people they value. If not interested, they avoid disliked items.

According to Kahan et al. (2017), educators must evaluate students' needs, interests, experiences, and preferences. Pleasant experiences might also spark interest (Berlyne, 1949). Clean, clear, and symmetrical experiences can create a pleasant experience, according to Tractinsky and Lowengart (2007). Balance designs are known to take less attentional resources to and analyze (Bhandari et al., 2017). Hence, the processing is streamlined, and design interaction is improved (Altaboli & Lin, 2011). In addition, according to WCAG 2.0 (2018), low vision preferred to view the content according to the preferences that work best for them for example landscape orientation which can increase the text size for them to view the content. Furthermore, in a study by Irvine et. al (2014), patients who want to read visually will gravitate toward a larger device that displays larger text, whereas patients who rely more on audio feedback may benefit from the smaller devices that take up less space. Hence, this study considered the landscape orientation in providing the content layout to the LV learners.

ii) Happiness

Meanwhile, Demirbilek and Sener (2003) defined happiness as a state of well-being and contentment. Thus, in their study, they summarise happiness in six different types of emotional response which are senses, fun, cuteness, familiarity, metonymy, and colour. Shedroff (1994) suggested senses are a response to communicate to others

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through our senses. This involves the sensorial design as appropriate media to deliver the message. These include the appropriate use of media, style, and technique, applicable to the technology of the situation, as well as an understanding of the human senses (Shedroff 1999).

Furthermore, according to the Design Guidelines for Children by Gilutz and Nielsen (2007), adding sound as one of the design guidelines will be beneficial to evoke children's positive emotional responses and draw their attention. For example, in a study of the development of a computer game, QuiQui's Giant Bounce (Höysniemi et al., 2003) is made up through control of movement and sound. The game imitates a child's movements and the use of children's voices.

The findings of the study show that children participating in usability testing enhance the experience. The "peer-tutoring" concept may be conveyed by imitating children's voices throughout application development. Goodblad and Hirst (1989) defined peer tutoring as "a system of instruction in which learners support one other and learn by teaching".

Goswami and Bryant (2007) stated that learning by imitation is one of the child's types of learning. This includes learning the relationship between the sounds that underpin language acquisition (Yahaya & Salam, 2009), such as imitating the children's voices in designing mobile applications for children.

In this context of the study, to cater to the needs of LV learners that have problems with their visual sense, delivering a message through multimedia content it is best to

combine both visual and audio elements despite their limited ability in eyesight they also depend on their hearing ability to aid in their daily communication (Azuwan, 2021).

Hence, in this study, the researcher incorporates the feelings in a positive emotional state in the design principles ignite the interest and happiness feelings of LV learners when interacting with the mobile application.

- ***Thought***

i) Positive perception

The emotional state elicits specific tendencies in peoples' thoughts, actions, and physiological responses (Lee et al., 2015). Nass et. al (2005) added in their study most psychologists agreed that it is impossible to have a thought or perform the action without engaging with the emotional system. Emotion is triggered by the thoughts, beliefs, values, and attitudes of the situation or events that occur (Demirbilek & Sener, 2003). Meanwhile, the study also found that emotional responses are not direct responses to objects but to thoughts about them. Emotions are transient psychological, physiological, and behavioural responses to thoughts, events, and social activities (Mustafa et al., 2008).

Schwarz (2002) argues "Theoretically, emotions are thought to reflect the ongoing, implicit appraisal of situations with relates to a positive or negative experience for the individual's goals and concerns". Positive experiences contribute to the full development of the cognitive, emotional, and social areas of the student (Twaróg-Kanus, 2020). Thus, a Cognitive Theory of Multimedia Learning (CTML) by Mayer

(2005) examines how designers implement cognitive strategies in multimedia development to assist learners to learn efficiently (Sorden, 2012).

Mayer (2005) has outlined eleven principles of cognitive multimedia design which are presented in Table 2.8 below.

Table 2.8

Principles of Cognitive Multimedia Design

Principles	Description
Multimedia	Instructional multimedia should at least have two modes of multimedia elements rather than using words only
Spatial contiguity	Placing words and pictures near each other. (Sorden, 2012)
Temporal contiguity	Present the words and the picture continuously. (Sorden, 2012)
Coherence	Exclude the irrelevant content in the same frame of the slide.
Modality	A combination of graphics and narration is better than graphics and text.
Redundancy	Graphic, narration, and text should not be in the same frame or slide. Exclude animation if there is already video.
Personalization	The instructor should speak in a conversational style rather than the formal style of conversation (Sorden, 2012).
Signaling	Enabling the user to easily recognize and learn information when using callouts, arrows, and highlighting the key elements.
Pre-training	Involve the user in pre-training on the objectives and key concepts they will learn about.
Voice	Use human voice in the multimedia presentation rather than computer-generated voice.
Image	The present of the image of the instructor provide meaningful learning

Based on Table 2.8 of the outlined principles of cognitive multimedia design, this study incorporates the signalling principles. The principle enables the user to acknowledge the functional button and address the user navigation correctly by name labelling on the button. The common accessibility issues arise due to neglecting this principle

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related to the button one of the commonly used elements involve in the existing mobile application for low vision (have been discussed in Chapter 1). This results in negative confusion, negative perception, and loss of navigation of the user especially for the LV learners in navigating the application.

Furthermore, Norman in his book entitled Why We Love (or Hate) Everyday Things (2005) stated that the human brain operates at three levels: the visceral (perceptually based), behavioural (expectation based), and reflective levels (cognitive based) aspects of design. Based on the mentioned emotional level, the design principles implemented at the "visceral" level are commonly related to cognitive-educational function developing perceptual and intellectual processes based on the study of the function of media technology by Nowakowska-Buryła (2005).

Mueller (2004) summarised in his review of the emotional design by Norman (2005) the key characteristics of the visceral level where the user is triggered by the appearance. This level acts as a good indicator in terms of signalling sensory satisfaction (Norman, 2005). Hence, this study implies button labelling using words and sounds to synchronize the user on what they see and what they hear when clicking the button. This creates the instant perception of appearance and pleasure to see a well-designed product (Aftab & Rusli, 2017), especially for LV learners. Moreover, emotion is long discussed as affected by perception (Mather & Sutherland, 2011). Furthermore, visceral design provokes quick and powerful perception from the viewer and commonly pleasant feelings are often elicited by viscerally well-designed products. This level encompasses the sensory components of what things look like and the feeling for the first emotional connection between the user and the product and it is

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connected to the instinctual part of human emotion (Norman, 2005).

ii) Positive State of Mind

Shirke et. al (2020) added emotions are referred to as a natural instinctive state of mind triggered by certain circumstances or moods. This is because emotions change due to internal and external stimuli and events as different emotions lead to different states of mind (Shirke et al., 2020). For example, a learning scenario of a study of different multimedia stimulus show a significant difference in attention and motivational level (Ng & Chiu, 2017). As a result, the experimental group which serves by positive stimuli such as additional emotional design (warm colors, round-face-like shape) performs better than the control group (greyscale, rectangle, and square shape).

The perception of the design between both groups is different resulting in different achievements. However, the experiment was tested on general children with normal vision. Therefore, acknowledging the learning style of the visually impaired is important to assist in developing the interest of a child in the teaching and learning process and determining the suitable learning material for them Children (Majid & Chaudhary, 2018).

Generally, the learning styles are studied in four types (Fleming & Baume, 2006) as (i) visual learners, (ii) auditory learners and (iii) Reading or writing learners (iv) kinaesthetic learners. According to the study on the Preferred Learning Style for Visually Impaired Children (Majid & Chaudhary, 2018), in contrast, the least preferred is the visual learning style. This finding leaves a question mark on the researcher why the visual learning style is the least option opted by the respondents. Moreover, the LV

learners still have the residual useful eyesight to interact with the multimedia elements. Hence, this finding yet further strengthens the need on exploring the best acceptance of visualization (size of text, contrast, or clarity of buttons) preferred by LV learners in this study. The visualization includes both text and non-text components such as buttons, icons, and images. Visualizations enhance cognition (Tversky, 2001). Visualizations can help individuals find places, explain operations, and understand systems. Appropriate design is design compatible with human perception and cognition (Tversky et al., 2020).

Hence, thought as an affective component of design principles for LV learners can elicit positive perception and positive state of mind from a perceptible appearance of the multimedia elements (size of text, contrast, or clarity of buttons) in the mobile application.

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- ***Action***

i) Navigation

Rachman's (1997) believes that one's thoughts and actions are intimately connected and/or equivalent. Human actions are those behaviours that persons have chosen to perform and perform for a reason (Winch, 2015). Related to a study, Alepis et, al (2006) has outlined ten students' action while engaging with the educational application in learning. All the actions were measured to identify the effectiveness of the mobile application during user testing. There are ten actions performed:

1) inattention mistake (the student may give the wrong or close to the right answer)

2) some knowledge mistakes

3) correct answer

4) the user reads the theory

5) the user reads a question from the test

6) extended navigation in the application

7) correct navigation

8) wrong navigation

9) absence of an action

10) action unrelated to the educational application

In this study, the researcher fonds to focus on the action of the user in navigating the mobile application. Ease of navigation may result in feelings of satisfaction when interacting with the application (Coetzer, 2017). This results in positive interaction during the learning. While the navigation design refers to the way the pages and the content are organized and laid out in terms of mobile application structural layout (tablet or smartphone).

The navigation design of an application has a significant impact on how much effort a user must exert to complete the navigation in the application (Vance et al., 2008). Furthermore, navigation implies the success and failure of the delivery of information on a mobile application (Kumar, 2016).

Consequently, an effective navigation design for a mobile application should include an intuitive, predictable, and consistent in its appearance. Navigation control allows

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users to navigate to the desired pages quickly and easily from any page in the application (Montoya-Weiss et al., 2003). Table 2.9 outlined the list of navigation guidelines for creating mobile learning applications (Kumar et al., 2019).

Table 2.9

Navigation Guidelines in Mobile Application

Guideline	Description
Navigation	Provide navigation options to move between different pages The navigation option should be on easy to find a place on the page Exclude horizontal scrolling Make important items reachable from the start page Maintain consistency in navigation options used emphasize links to seek attention from users Avoid too many images with links. Use colour changes to indicate to users when a link has been visited. Minimize the number of clicks.

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Chan et al. (2002) suggests that the navigational design for handheld devices and browsers should adopt and resemble similar to Web browsers. Based on above Table 2.9, the navigational design suggested by Kumar et al. (2019) is common a non-linear navigational design. There are two types of navigational design the Web design which (i) linear and (ii) non-linear (Hsu et al., 2009). In the other words, the two types of navigation are acknowledged as static (fixed path) and dynamic (following user's needs) respectively. An application with linear navigation is solely controlled by the system (Martin, 2008). The users have no control over the sequence of the content of the mobile application. The navigation will simply move forward and backward.

Whereas, in non-linear navigation users have greater control over the content compared to linear navigation. Based on the recent studies (refer to Table 2.10) in the development of the mobile application for the visually impaired (both low vision and

blind users) most of them were applying the non-linear navigational design.

Table 2.10

Types of Navigation Design of The Existing Mobile Application

No	Mobile Application	Types of Navigation	
		Linear	Non-linear
1.	All Appointments (Ghidini et al., 2016)		√
2.	Sejahtera Lestari (Mohamad et al., 2018)		√
3.	Tourism for All (Ceccarini & Prandi, 2019)		√
4.	mySugr (Pagano et al., 2020)		√
5.	FarmaceuticApp (Madrigal-Cadavid et al, 2020)		√
6.	Serious Game (Othman et al., 2020)		√
7.	MagVi (Thakur et al., 2021).		√
8.	MusA (Ahmetovic et al., 2021).		√
9.	Kai Access (Diskapama & Fauzi, 2021)		√
10.	WordMelodies (Ahmetovic et al., 2021)		√

Based on the listed existing mobile applications in Table 2.10, the most preferred types of navigation will allow users to freely navigate and control their path (Martin, 2008) as there is no specific path restricted by the system which resulted in greater flexibility in interacting with the content. Furthermore, designing navigation interfaces for people with visual impairments must be appropriate for flexibility, adaptability, and feedback (Brady et al., 2015).

Hence, incorporating ease of use in the term of navigational design aimed to provide an affective design principle for the user as navigation implies the success and failure of presentable information on a mobile application (Kumar, 2016).

ii) Interaction

In addition, action-based techniques can improve users' learnability and understandability through interaction (Shamsuddin et al., 2011). Thus, in their study,

they also outlined the user's interaction such as input interaction through keyboard or clicks or text input to measure the time consumes towards a user interface. The result in delay or lag of action may result in uncertainty in action to complete the task. The findings will be resulting to measure which is the most preferred interaction that can increase the user's learnability and understandability. Furthermore, users' interactions on a system often indicate users' interest (Mueller & Lockerd, 2001).

Interaction can be classified into three types which are (i) student-to-student, (ii) teacher-to-student, and (iii) student-to-content (Evans & Gibbons, 2007). Thus, in their study, they are using the interaction of student-to-content interaction. According to Evans and Gibbon (2007), "interaction involves a sequence of three actions: initiation, response, and feedback":

1. Initiation: enables users with a control feature such as a button to allow them to push or interact in response to a move action.
2. Response: the learner presses the button or control features that appeared in the next action.
3. Feedback: the next page or information on the same page is presented because of the learner pushing the button in the last action sequence.

In addition, Evans and Gibbons (2007) have conducted two experiments (interactive and non-interactive) to determine whether interaction can help users improve their learning or not. According to the findings, students who had viewed the interactive multimedia presentation had higher scores on the problem-solving test and needed less total time to finish both the memory and problem-solving tests (Evans & Gibbons,

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2007). Chen and Catrambone (2014) observed that learners were more motivated and engaged in the learning process when they used interactive materials. Learners can also benefit from the use of interactivity to help users generate meaningful learning. Hence, the findings of this study propose implementing the affective design principle to improve LV users' learning using mobile applications.

In conclusion, all the suggested affective four dimensional design principles based on four dimensional component can enhance their learnability in mathematics subject. By providing a set of affective four dimensional design principles through the development of the AMM4LV application, the mobile application can be used to provide positive emotions to LV learners.

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2.7 Mathematics Mobile Learning Application

In the last decade, there have been significant shifts in the capabilities of technological innovation. As a result of the increasing prevalence of smart mobile devices, a growing number of people are beginning to believe that a new type of educational software could be an appealing way to deliver instruction to youngsters, provided that the software is well-designed and appropriate for the children's age. Technological abilities appear to emerge in children as early as infancy, with most of this learning occurring inside the family environment through observation and imitation of their family members' digital behaviours. Children's education, in the opinion of their parents, is made more difficult until they understand digital technologies and develop digital abilities. As a result, they feel that schools must play an important role in providing digital literacy instruction to students in the lower age groups. When

technology is used to aid in the development of children, it is most effective when it is tailored to their needs, age, needs, interests, and sociocultural context.

Nowadays, young children are immersed in a digital culture that includes the use of advanced gadgets such as electronic tablets, electronic readers, and smartphones, which enable them to discover and engage with several applications as well as different types of print and digital text. Some studies have analysed the effectiveness of advanced interactive technologies, such as tablets and other smart handheld mobile devices, which have the potential to provide significantly more learning possibilities (Giannakopoulos et al., 2018) that are now available on traditional platforms (Alade et al., 2016). For instance, the findings of Chaudron et al. (2018), determined that tablets are the most popular type of device preferred by young children for viewing online movies, playing interactive games, drawing, listening to music, and conducting informational searches.

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For parents of young children, this gadget has a few major advantages, including a touchscreen display, mobility, and the advanced usability of touchscreen technology (Chaudron et al., 2018). Because of this, it is frequently used in societies that see it as a "family" device or an asset for children and young people (Chaudron et al., 2018). Consequently, children will have access to educational applications and designs that are age-appropriate for their development, as well as the ability to design, create, and publicly express their thoughts (Papadakis et al., 2018).

While there has long been debate and controversy about the introduction of technology in the context of early childhood education, there is now widespread agreement that young children must have some access to software to become familiar with a wide

range of software programs and to learn how to use them (Marsh et al., 2017). Schools may play an essential role in the development of digital competencies, which can be heightened even further by incorporating digital technology into the classroom as active learning tool. Numerous important factors influence the adoption of digital technological gadgets as instructional tools in early childhood education, all of which are discussed in detail below. According to Kalogiannakis and Papadakis (2019), the most important element determining the future use of new interactive technology in the learning process is prior experience with this sort of technology.

The adoption of smart mobile technology is mostly motivated by the children's belief that it is simple to use and that it provides them with significant benefits in early childhood education (Kalogiannakis and Papadakis, 2019). To put it another way, children who have demonstrated an exceptional aptitude for using modern mobile devices have learned to appreciate the educational benefits of these emerging technologies, as seen by their ability to recognize the benefits in their respective areas of science study (Papadakis and Kalogiannakis, 2019). The use of digital technology for instructional purposes may also have a beneficial effect on parents' positive attitudes toward the usefulness of digital technology as a learning tool, and it may encourage parents to advocate for their children's digital education (Chaudron et al., 2018).

This study is primarily concerned with the need of an affective learning approach to mathematics by means of mobile devices that are associated with the needs of LV learners. The goal is to provide a better understanding of the influence of assistive

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mobile technologies on LV learners' learning procedures as well as the potential of mobile applications in AT.

2.7.1 Existing mobile application

This study selects ten mobile applications which were outlined in the past five years (i.e. 2016-2021) from various countries and respectable journals. They are (i)All Appointments (Ghidini et al., 2016) (ii) Sejahtera Lestari (Mohamad et al., 2018), (iii) Tourism for All (Ceccarini & Prandi, 2019), (iv) mySugr (Pagano et al., 2020), (v) Farmaceutic App (Madrigal- Cadavid et al., 2020), (vi) Serious Game Prototype for Low Vision Children (Othman et al., 2020), (vii) MagVi (Thakur et al., 2021), (viii) MusA (Ahmetovic et al., 2021), (ix) Kai Access (Diskapama & Fauzi, 2021) and (x) WordMelodies (Ahmetovic et al., 2021).

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(i) All Appointments

All Appointments by Ghidini et al. (2016) is an accessible mobile application built to assist visually impaired individual which is having LV or blindness in scheduling appointment. This application acts as a replacement for using the built-in calendar application on a mobile device. This application works through voice commands and multi-touch using high contrast colour between background and foreground colour for a better view for low vision users. Figure 2.3 shows the snapshots of All Appointments.

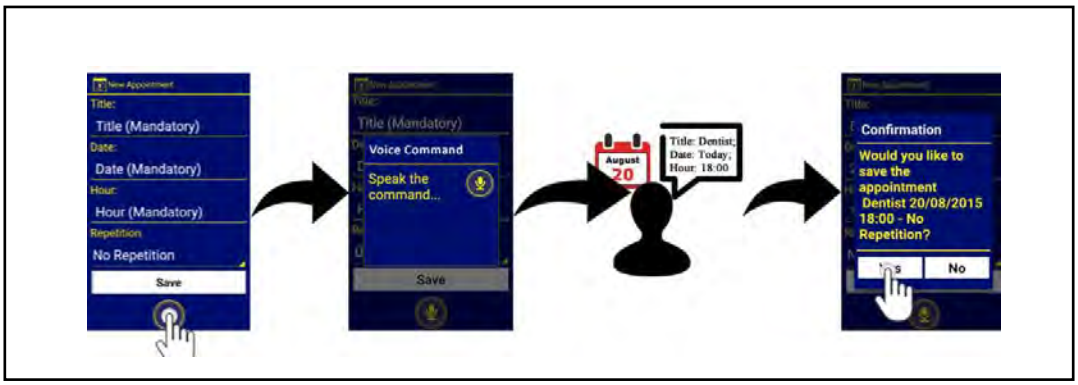

Figure 2.3 Snapshots of All Appointments

The main functionalities of this application are to create, delete, edit, and read appointments, and filtering search of appointments. The development of the prototype involves investigating the user experience between the built-in calendar application and the proposed prototype. The voice command such as audible feedback received from the prototype seemed to act as a positive added element in the design.

However, based on the results and findings of the study found that the graphical interfaces of the application still need room for improvement. The common issue that occurs are locating the button. For example, the button for the voice command does not stand out, occasionally causing the user to tap beside the button. This will cause the user to take some time for navigating to the next page. Besides, based on the user's feedback the layout structure is also hard to understand as some of the users had trouble with the arrangement of the fields. This requires them to get help from the observer. Hence this issue has addressed to lack of ease of use for navigation one of the affective elements proposed in this study. Whereas the study also did not discuss any of the affective elements in their design.

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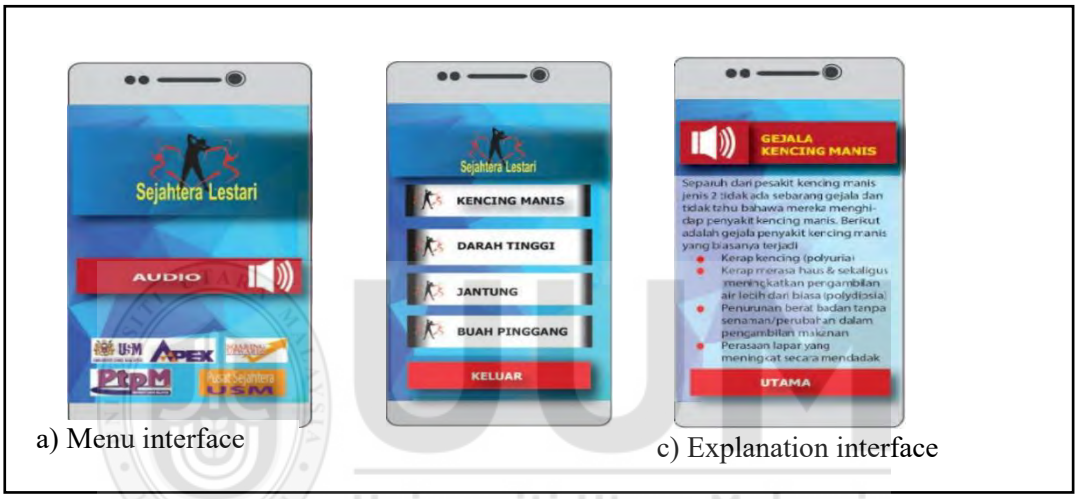
ii) Sejahtera Lestari

Sejahtera Lestari by Mohamad et al. (2018) is a mobile health application providing health information to the visually impaired individual (including both low vision and blindness) about the four series of major chronic illnesses in Malaysia, such as Heart Disease, High Blood Pressure, Diabetes, and Kidney disease. This mobile health application is also associated with voice recognition and talkback functions.



a) Menu interface

c) Explanation interface

Figure 2.4 Snapshots of All Appointment

As exhibited in Figure 2.4, shows part of the snapshots of the mobile health application. The whole application was built by including interfaces of i) Introduction, ii) Symptoms, iii) Nutritional recommendations, iv) Preliminary treatment (prevention), v) Prayer and Alternative Suggestions, vi) FAQ (Doctor Advice). The overall development of mobile applicate was integrated into only a few multimedia elements such as text, audio, and graphic. Although the result of the usage of this mobile application showed a positive reaction from the students, based on the discussion section, the user insisted on enlarging the size of the text for a better experience. Hence, this mobile application still does not cater to the needs of LV

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learners due to the visualization aspects which demote the affective element in their design.

iii) Tourism for All

Tourism for All by Ceccarini & Prandi (2019) is a mobile application in assisting visually impaired tourists to perform cultural and tourist activities. The application acts as tourism facilitation that enables them to access public places and services. Figure 2.7 depicts the snapshots of the interface design of Tourism for All.

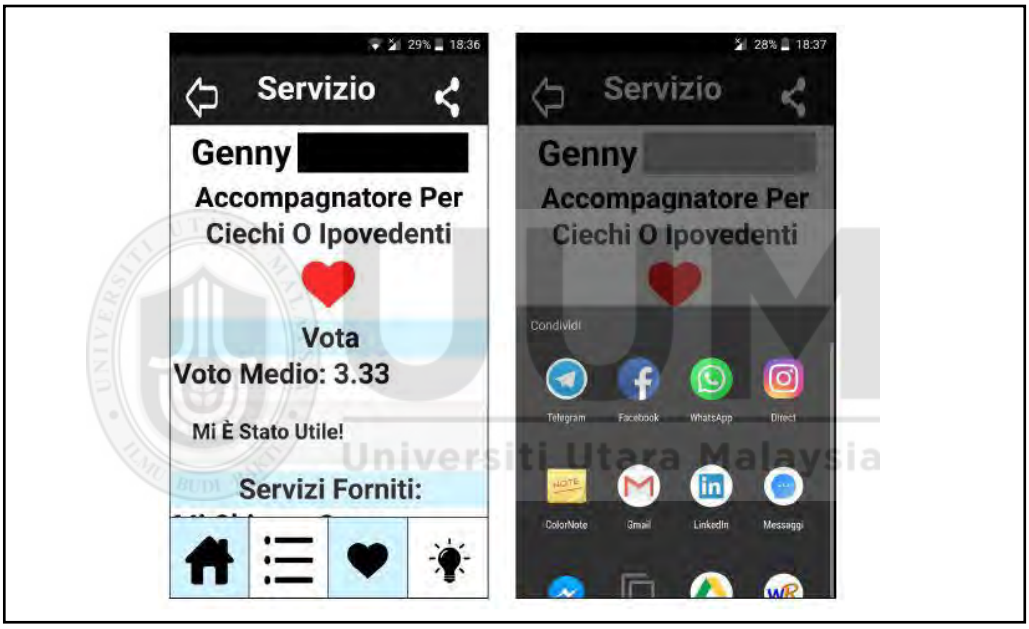

Figure 2.5 Snapshots of Tourism for All

Based on Figure 2.5 this application comprises four sections which are home, list of services, preferred services, and recommended services. The most facilitating feature of this application that users can customize the colour background and foreground and text style. In addition, this application utilizes gamification strategies to engage with the user's feedback and comments about their experiences with the services provided in the application. The users will be nominated points and assignment of badges

according to the number of points collected. This strategy will encourage the user to use the application continuously.

However, there is still an issue arising on the sharing button function. The developer directs the share button function to the built-in the page of collections of sharing platform. It is better to put all the sharing links on a one page illustrated by bigger icons for ease of sharing experience. Hence, this interrupts the user's interaction with the mobile application and address to lack of an affective element in the design.

iv) mySugr

Pagano et al (2020) come out with a mobile application named mySugr (Figure 2.6) which adopts accessible audio-visual translation in mobile technology. The design of application needs to be carefully designed by characterizing and naming the buttons in the application, so it is readable by the screen reader. The study stated that little attention has been paid to the need for accessibilities in visual content (buttons, menus, pickers, sliders, switches, and others) for actions and navigation of the application.

Figure 2.6 Snapshot of mySugr

However, based on the results of the research, stated mySugr is producing nonsensical text read by a screen reader plus is not compatible with voice dictation, in the Android screen reader, TalkBack. Furthermore, some of the texts are not relevant to understand, for example, hyphens inside the images, which can be excluded to be read. So, minimizing the description will meet the guideline of non-text content should be ignored by the screen reader.

Moreover, based on Figure 2.6, the colours of the circles indicate the results of blood glucose levels, which are green, red, and orange which also acts as an avatar that produces sound. All the levels ranging are “not in target”, “in target” and “not in target but still acceptable” conveyed by the colours in mySugr the colours are translated through the audio produced by the avatar.

However, based on the interview results, most of the users were not aware of the existence of the avatar. Some of the users accidentally tap on the avatar and only then realize the existence of the features. Hence, the message on the glucose level that needs to convey to the user is not achievable to the user.

In addition, lack of a magnifying resource for the use of low vision users. The application is not allowing screen enlargement hence the text in the mySugr remained illegible for one of the severely low vision users during the observation. Thus, based on the accessibility issues that have been pointed out lead to a bad user experience for the user with low vision which affect their motivation in using the application in the future.

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v) FarmaceuticApp

Madrigal-Cadavid et al. (2020) introduced FarmaceauticApp a mobile application for drug information for people with visual impairment (low vision and blind), which allows them to access information for the appropriate use of medicines. People with visual impairments present to have difficulties in accessing the labels of information of medicines. Figure 2.7 shows snapshots of FarmaceuticApp.

Figure 2.7 Snapshots of FarmaceuticApp

Based on Figure 2.7 the functional requirements highlighted to make the application more accessible for the visually impaired person are on the search and settings page.

The search methods incorporate four methods to search the acquire drug information which is through barcode capture, image capture, voice command, and input text. Besides, through the setting page, user can activate or deactivate the voice assistant, and sound, and resize the text to a preferred level or visual impairment. However, according to the functional requirements based on priority, 1: Must have, 2: Should have, 3: Could have, 4: Won't have at this time, the setting page is labeled as 3 (Could have). This may be due to the arrangement of the pages being different, the user might need to go back and forth between the page setting to adjust the size of the text.

It is more appropriate if the developer set it to a fixed size and increases the clarity of the text between text and the background as an alternative to the adjustable size setting function. Moreover, based on the usability test for the text reading, the time required by the low vision to read the text was two to four minutes. This shows that even with the functional requirement of screen magnification has been added to the application the low vision user still requires more time to read the text.

vi) Serious Game Prototype for Low Vision Children.

The development of Serious Game for Low Vision Children (Othman et al., 2020) is based on the play-centric design which acts as a strategy that and prioritizes the player experience throughout the design process, resulting in increased audience participation through meaningful interactions and complex storylines. This type of game was designed carefully for LV learners considering the most appropriate accessibility

elements implemented in the design of mobile applications such as depicted in Figure 2.8.

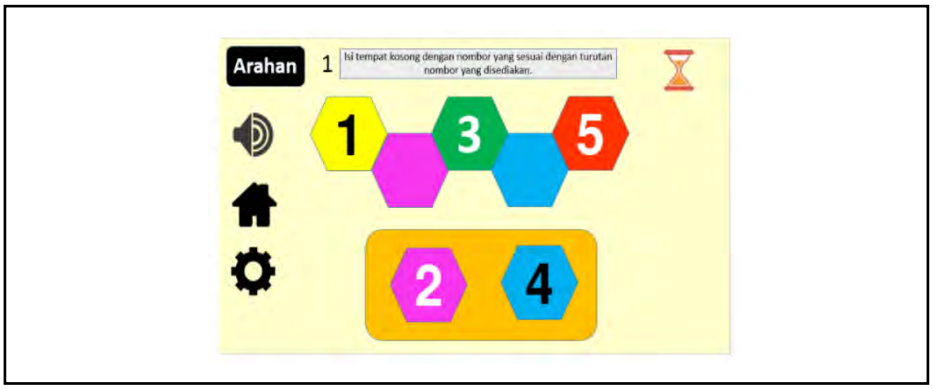

Figure 2.8 Snapshots of Serious Game for Low Vision Children

Accessibility elements were implemented from various studies which have been summarised in this study into five types of accessibility elements, multimedia, navigation, language, object speed, and screen design. On the other hand, the developed prototype also includes characters from various animals so children will identify better with the character chosen (Sudarmilah et al., 2015). However, the mobile application still needs to reconsider the suitable colour for the application to have a larger distinction between the subject and the background. In addition, considering that there is an audible text guiding the user while playing, the text displayed still must be enlarged so that the user can acknowledge what they hear with what they see. Hence, both interactions of seeing and hearing are adhered to each other and improve the experience of LV learners with the application.

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vii) MagVi

MagVi (Thakur et al., 2021), is a mobile application designed for LV in magnifying video. The proposed application is therefore designed to provide magnification of the video to pan and zoom over the videos, movies, or Youtube videos and make it more user-friendly for low vision. This application primarily aimed to make dynamic content accessible for low vision. Figure 2.9 depicts the snapshots of the interfaces of the MagVi application.

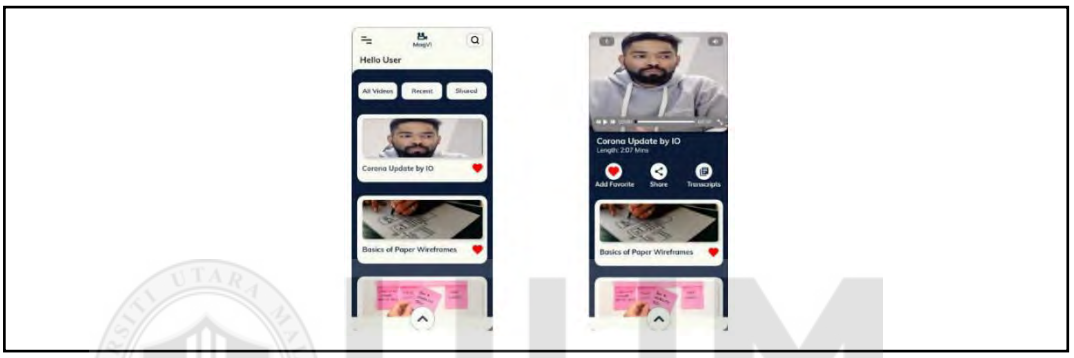

Figure 2.9 Snapshots of MagVi

The interfaces are applicable for a visually impaired person specifically for low vision. However, with the remaining sight that LV learners have, the application seems to lack in the terms of visual attraction for LV learners. Thus, this will demote the value of affective in the mobile application interaction with the user.

According to the usability characteristics in Gestalt theory, (similarity, continuation, closure, proximity, figure or ground, and symmetry or order) that were implemented in the design of the MagVi application, showed a positive result in the usability evaluations of the mobile application. However, based on the usability testing in the study, the findings demonstrate that there is the problem with navigation, colour contrast, and size of the icon that does not meet the LV preference.

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Hence, usability testing has discovered a few results that are needed to be improved. However, there are a few features such as dark mode or light mood that can be chosen to make the application more adaptable to LV users. The goal of raising the satisfaction of the user with the usability of the design promotes a positive user's emotion and experience while using the application.

viii) MusA

Figure 2.10 depicts a mathematical mobile application called MusA, a prototype of a mobile application project by Ahmetovic et al. (2021). It specializes for LV users. This application is built to provide interactive artwork descriptions for LV visitors at the museum. This application provides useful functionalities and enhances the interest of LV to visit museums through Augmented Reality. Figure 2.10 the interfaces of the MusA application.

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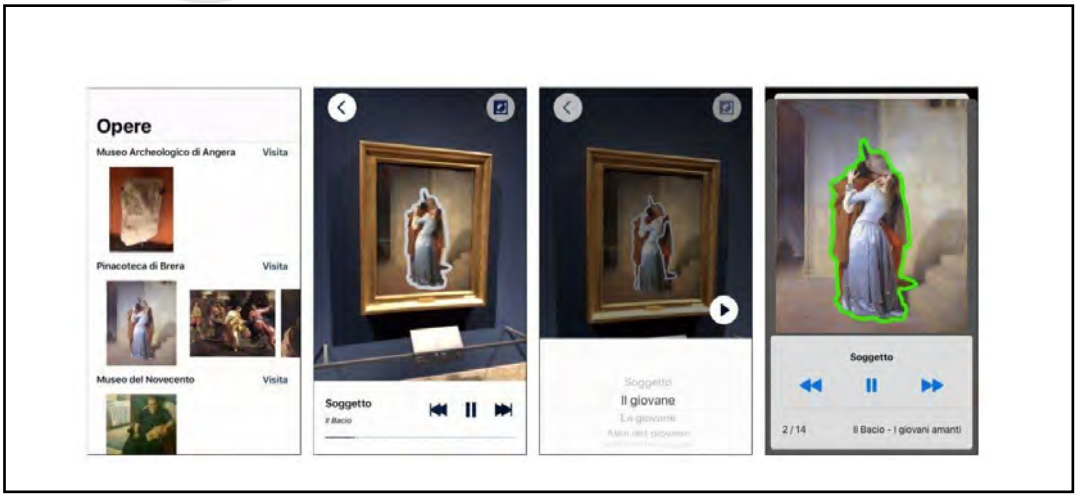

Figure 2.10 Snapshots of MusA

Based on the interfaces portrays in the snapshots shown in Figure 2.10 the vertical layout oriented for the application seems useful in terms of ease of use in navigation for LV users. The users point the camera to the actual artwork in the museum and the

application detect the artwork and started to describe the history of the artwork through the audible description. This application is more engaging than a traditional audio guide.

Overall, MusA seems interesting in terms of functionality. However, based on the result of the second iteration of prototype testing, there are still accessibility issues to satisfy the needs of LV in the application. The issues are related to the audio speed which is too fast. The audio description also cannot be moved or forward. The low vision users might be distracted for a short time and need to re-start the audio description from the beginning. Furthermore, the feedback from the application is still not sufficient as the user does not realize that the artwork has been recognized and kept searching before realizing the feedback appears as an overlay image with low contrast. LV learners might encounter a problem in distinct the information emphasized with the background. Hence, this led to confusion and increase the complexity for the LV learners in using the application. Furthermore, based on the results also noted that the application has a small touch area. This led to an error in navigation as the user accidentally click the unintended button.

Hence, based on the mentioned accessibility issues discussed the application needs to integrate more affective four dimensional design principles to cater to the needs of LV users to assuring the continuous usage of the application in the future.

ix) KAI Access

A public transportation mobile application named KAI Access was proposed by Diskapama & Fauzi (2021) to facilitate services ticket booking of a train, and

scheduling journeys by providing fast transactions through online access. However, the original version of the mobile application was developed for the general user while people who have disabilities will encounter a problem while using the application.

As usual, the interfaces of the actual application were designed using the general design guidelines which the study has outlined the accessibility issues encounter in KAI Access through the size of text, text colour, graphics, background colour, featured icon, and button. However, the study has overcome the issues by improving the guidelines that satisfy the LV needs as shown in Figure 2.11.

Figure 2.11 Snapshot of KAI Access

Based on Figure 2.11, this indicates that the study has adapted a good colour contrast between the background the foreground of the overall interface of the design. However, based on the results of evaluation of the study indicates that there still issues involving the accessibility if the mobile application. multimedia elements so well. However, without considering the aspects of visual, audible, and affective features in

the application to be a perceptible mobile application for low vision learners it will not satisfy to the needs of them in learning through mobile application.

x) WordMelodies

Figure 2.12 depict the English basic literacy skills language mobile application called WordMelodies, a project by Ahmetovic et al. (2021). It specializes for visually impaired (low vision and blind) children in primary school. There is a discussion on the accessibility issues of the interaction design of the WordMelodies.

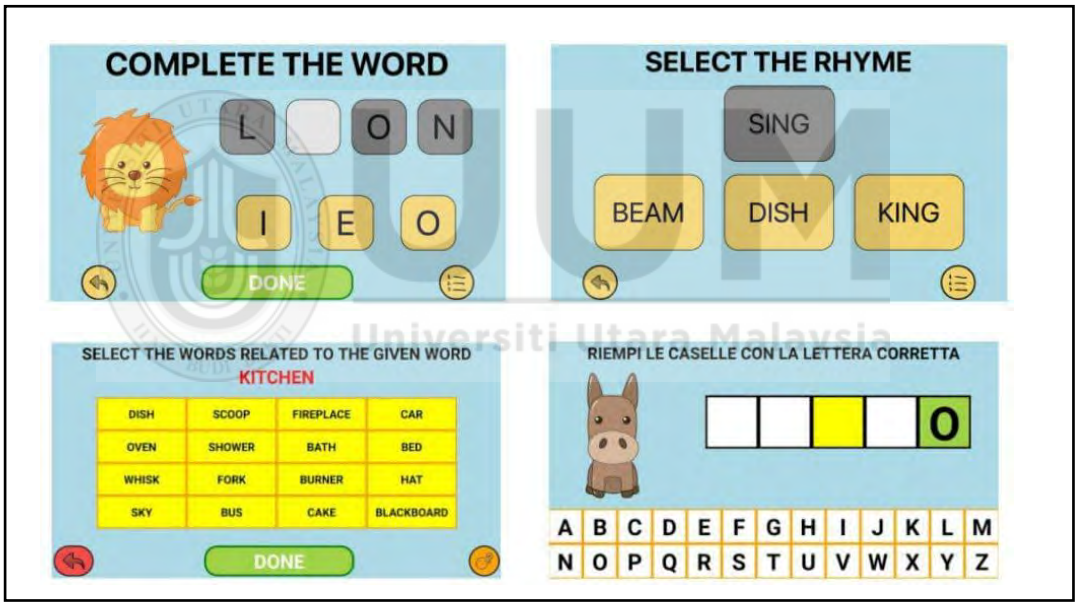

Figure 2.12 Snapshots of WordMelodies

However, based on the snapshots in Figure 2.12 it can be concluded that static graphics with audio icons (Gaver, 1986) has been utilized to attract young visually impaired children in utilizing the mobile application. On the other hand, this application is made of two types of exercise families which involve two types of interaction design. Upper snapshots depict “drag & drop” questions that require the users to double-tap and hold

the icon. While lower snapshots depict a “multiple choice” question that requires the user to just tap the answer. The variation of interaction may elicit the student’s motivation.

Based on the analysis, WordMelodies is still having issues with the interaction. The application is incorporating the drag & drop interaction which involves the swipe gesture or often referred to as a flick gesture. React Native, the software used to develop the application does not support an accessible drag & drop. This problem is caused by the fact that the software has an internal order of user interface elements, and it is impossible to change the accessibility focus order of these elements. The user will interact with the gesture of left, right, up, and down, vertically, and horizontally, respectively without the interaction of the swipe gesture (flick and fling freely to the desired direction). While this part limits the application's usability, however, it is still feasible to explore every aspect of the user interface of the mobile application.

According to the mobile application that has been built, there is still a need for a more specific and interactive design to provide users with a more positive experience when navigating the application.

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2.7.2 Reviews on Existing Mobile Mathematics Application Interface Design to the Study.

There has been an analysis of the ten different mobile application designs to determine the common accessibility issues of the interfaces based on the result of user testing in the discussion of the studies. According to the results of the analysis, review, and limitation of the existing design interfaces for mobile applications, it was discovered that most of the accessibility issues discovered are the same, and most of the developed mobile applications were missing in terms of accessibility, especially for those with visual impairment that has been noted in the Table 2.11.

Table 2.11

Accessibility Issues in Existing Mobile Applications

No	Mobile Application	Limitation	Discussion
1.	All Appointments (Ghidini et al., 2016)	Accessibility	1. Layout structure 2. Colour contrast
2.	Sejahtera Lestari (Mohamad et al., 2018)	Accessibility	1. Small size of text 2. Delay in voice recognition
3.	Tourism for All (Ceccarini & Prandi, 2019)	Accessibility	1. Small size of button
4.	mySugr (Pagano et al., 2020)	Accessibility	1. Not aware of functional button 2. Nonsensical text read by screen reader
5.	FarmaceuticApp (Madrigal-Cadavid et al, 2020)	Accessibility	1. Small size of text
6.	Serious Game (Othman et al., 2020)	Accessibility	1. Small size of text
7.	MagVi (Thakur et al., 2021).	Accessibility	1. Lost in navigation 2. Button colour is too light 3. Small icon size
8.	MusA (Ahmetovic et al., 2021).	Accessibility	1. Problems with audio playback. Too fast audio speed. 2. Feedback does not clear as insufficient colour contrast 3. Small touch area of button

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9.	Kai Access (Diskapama & Fauzi et al., 2021)	Accessibility	1. Small size of text
10.	WordMelodies (Ahmetovic et al., 2021)	Accessibility	1. Text clarity

Based on Table 2.11 even though there are design principles, aspects, and accessibility feature in the models that were found to be appropriate for adaptation in this study, they still do not fully address the affective aspect for LV learners as a set of principles for mobile application providing emotional experience when interacting with the application. The issues in the size of text and the clarity of the icons were still found in their findings result in a poor experience in interacting with the mobile application. The issues interrupt the process of learning and understanding the content. The most essential thing to note is that the existing models are not suppressing the affective aspects that will draw attention and enhance the motivation of LV learners. None of the studies provide elements that are specifically revised to enhance the user's emotion.

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2.8 Accessibility Guidelines

The World Wide Web Consortium (W3C, 2018) refers to accessibility as the process of removing obstacles that restrict users from communicating and interacting with the web. Meanwhile according to Acosta- Vargas (2018) accessibility refers to the degree to which all people may use or access an object or service, regardless of their technical, cognitive, or physical limitations. Accessibility is a term that describes techniques, methods, and theories that are used to make media, in all of its forms to be more accessible to individuals who are disabled. Furthermore, according to ISO FDIS 9241-210, accessibility is described as "the ability of a product, service, environment, or facility to be used by people with the broadest range of capabilities" (ISO, 2010). This

definition broadens the scope of the concept of usability to include a more diverse range of users including persons with disabilities. In addition, accessibility is also taken into concern in the design of the building to accommodate wheelchair accessibility (Kankovsky & Dedic, 2020) and accessibility in transportation by integrating the universal design principles and the criteria of accessibility of transfer centers for disabled people in urban areas (Gören & Berköz, 2018).

On the other hand, the World Wide Web Consortium (W3C) is dedicated to ensuring that the web achieves its full potential, which includes promoting a high level of usability for those who are disabled. While the Web Accessibility Initiative (WAI) is an initiative of the World Wide Web Consortium (W3C). WAI is a member of W3C and follows the W3C Process for establishing web standards.

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The existing guidelines outlined by W3C are WCAG 2.0 which was published on 11 December 2008, and WCAG 2.1 which was published on 5 June 2018. They are organized under four principles: perceivable, operable, understandable, and robust design. The success criteria for each guideline are testable and are classified into three levels, ranging from A, AA, and AAA. The differences between the WCAG 2.0 and WCAG 2.1 are minor, but they are very crucial to ensuring that increasingly mobile-focused lifestyles remain both inclusive and accessible. The 17 new criteria are important in ensuring that the web and applications of the future are mobile-friendly and inclusive for all users.

2.8.1 Accessibility of Mobile Application

A mobile application is software that can be a native, web, or hybrid application (Jabangwe et al., 2018). Mobile applications communicate better than desktop programs and are easier to install and update due to their small size and flexibility to adapt to mobile devices' technical limitations (Acosta- Vargas et al., 2019).

Meanwhile, the number of application downloads is expected to rise in tandem with the continually increasing global number of mobile phone users. The Google Play store currently has more than 2 million apps available for download, while the Apple App Store has more than 1.83 million apps accessible for download as of 2019 (Statista, 2021). However, many applications developed in helping with daily life activities are not all accessible, where which indicates that will be large numbers of users cannot get the benefits of the application, especially disabled persons (Acosta- Varga et al., 2020).

Study related to accessibility research, and the design of mobile application interfaces have garnered a significant amount of interest. A steadfast focus on this topic has been spurred by the significance of providing users with disabilities with barrier-free access to mobile applications to foster social inclusion. According to the preliminary survey conducted by the researcher, the most common issues that arise when utilizing a mobile application include difficulty reading text with low contrast between the text and the background, inability to access audio information, and difficulties navigating through a mobile application, among other problems.

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The term "mobile accessibility" refers to the process of making websites and applications more accessible to individuals with disabilities who access them through mobile phones and other devices. The Web Accessibility Initiative (WAI) addresses accessibility concerns and provides guidelines for designers and developers, considering the fact that people interact with the web through a variety of devices. Furthermore, mobile accessibility is covered in existing W3C WAI accessibility standards or guidelines. There are no separate guidelines for mobile accessibility.

According to Damaceno et al. (2018), the accessibility of mobile devices refers to the ability to interact with the operating system of mobile devices in an understandable manner. People with visual disabilities face a number of challenges while using mobile devices, and this paper provides a comprehensive overview of the issues they face. It also proposes a number of accessibility recommendations to guide future research.

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Furthermore, according to El-Glaly et al. (2018), mobile applications should be made available to everyone. Nonetheless, many of the most widely used applications still lack adequate accessibility features.

Meanwhile, Eler et al. (2018) noted the importance of ensuring that people with disabilities can use mobile applications without feeling excluded, however, they also noted that developers do not have access to any tools to help them determine whether the user interface is accessible to people using the screen readers. As a result, the development and evaluation of mobile applications are laborious and time-consuming processes.

On the other hand, all the requirements also known as "success criteria" from version 2.0 are included in version 2.1. All the requirements of success criteria for version 2.0 are the same as those for version 2.1. However, WCAG 2.1 adds 17 success criteria to address mobile accessibility, people with low vision, and people with cognitive and learning disabilities. The differences between the WCAG 2.0 and WCAG 2.1 are minor, but they are very crucial to ensuring that increasingly mobile-focused lifestyles remain both inclusive and accessible. The 17 new criteria are important in ensuring that the web and applications of the future are mobile-friendly and inclusive for all users.

2.9 Multimedia Learning Theory

Students are able to strengthen their mental development to learn more thoroughly with well-designed multimedia content (words, pictures, illustrations, animations, and narration). This is in contrast to the traditional mode of communication, which only incorporates words (Mayer, 2003). In light of this, Mayer and his friends have conducted research into the characteristics of multimedia display and its effects on human beings (Doolittle, 2002; Mayer & Moreno, 2003; Mayer 2008; Mayer 2010). From this, they derive thirteen principles depicted in Table 2.12.

Table 2.12

Principles of Multimedia Learning Theory

Principles	Description
Multimedia Principles	Students learn better from words and pictures rather than words alone.
Spatial Contiguity Principle	Student learns better when the combination of words and pictures on the page or screen are presented near rather than far from each other.
Temporal Contiguity Principle	Student learns better when combination of words and pictures that presented simultaneously rather than successively.

Coherence Principle	Students learns better when extraneous words, pictures, sounds are excluded rather than included.
Modality Principle	Student learns better from animation and narration rather than animation and on-screen text.
Redundancy Principle	Student learn better from animation and narration rather than animation, narration and on-screen text.
Individuals Principle	Design effects are stronger for low-knowledge learners rather than for high knowledge learners and for high spatial learners rather than low spatial learners.
Signalling Principle	Students learn better when cues that highlight the organization of the essential material are added.
Segmenting Principle	Student learn better when a multimedia lesson is presented in user-paced segments rather than as a continuous unit.
Pre-training Principle	Student learns more deeply when they receive pre-training in the names and characteristics of key components.
Personalization Principle	Student learns better from a multimedia presentation when the words are in conversational style rather than in formal style.
Voice Principle	Student learn better when the words in a multimedia message are spoken by a friendly human voice rather than a machine voice
Image Principle	Student does not necessarily learn more deeply from a multimedia presentation when the speaker's image is on the screen rather than not on the screen.

Based on Table 2.12, the principle that has been utilize in the construction of affective design principles in this study is voice principles where voice of children has been used as narration throughout the application. Chapter 5 details this connection. Example of works that adapt the multimedia learning principles is development of courseware to strengthen the students' character (Septiani et al., 2020). The findings in the study based on the expert validation, teacher questionnaire, and student questionnaire collectively indicate that the multimedia learning principles exhibit

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feasibility for educational implementation and demonstrates efficacy in enhancing students' character development. Another work is multimedia learning theory as the theoretical basis for the development of more effective digital tools with the use of films and subtitling (Kanellopoulou et al., 2019).

The aim of this study is to construct the affective design principles for low vision learners and further act as a reference to other studies in developing interactive multimedia presentation. There are four components underlying this study which are emotion, feeling, thought and action. This shows the importance of concerning the multimedia aspect in designing multimedia learning content to make it useful to the intended user.

In the context of this study, all principles are applicable to be applied since this study is to construct affrctive design principles for multimedia learning content application. However, since the intended users are low vision learners, the princples needs to be used properly in order to be affective in terms of four dimensional design principles; emotion, feeling, thought, and action.

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2.10 Summary

This chapter has provided a succinct explanation of some relevant information that led to the conducting of this study. It begins with an overview of assistive technology and explores the different types of assistive technology that are available to assist PWDs in their daily lives. Afterward, the study moves on to the definitions of disabilities, which express the current state of people with disabilities in Malaysia, notably the trend in the number of people with disabilities over the past five years (2016-2020). Following that, the use of mobile applications in the learning environment is discussed, and an analysis of the existing educational mobile

applications is carried out as part of the investigation. Next, a discussion on accessibility guidelines followed by outlining the related guidelines to be implemented in this study. Finally, a discussion of affective four dimensional design principles, followed by the selection of the set of affective design guidelines that is relevant to the development of an affective designed mobile application for LV learners.

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CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

This chapter highlights the research design by defining the method and procedures used to achieve all of the research objectives described in Chapter 1. The Design Science Research Method (DSRM) is adopted, and it has been widely employed in Information System (IS) research. The five steps comprised of the method: (i) awareness of the problem, (ii) suggestion, (iii) development, (iv) evaluation, and (v) conclusion, have been elaborated to match with the activities to accomplish each objective of the study.

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3.2 Rational for Using the Qualitative Approach

Qualitative research finds meaning in a phenomenon through a natural and descriptive approach (Bryman, 2014; Kolb, 2012). The natural approach defined in the study is to acquire an actual data source from the natural background. In this regard, this study concerns with the phenomenon of LV learners as discussed in Chapter 1. The researcher got involved in an educational setting in the special needs primary schools. The rationale of this study to be conducted is as follows:

i) The main subject of the study is LV learners in primary schools. This indicates that they are still children. This drives the research to have a well-structured plan to conduct the research works. A naturalistic approach needs to be implemented in an effort to gain an understanding of the LV learners while conducting this study.

ii) Low vision learners are classified as special needs individuals that require extra attention. According to Bryman (2014), qualitative research ignoring action, utterance, and gesture means losing an important meaning. Hence, their actions and behaviours give valuable data to this study. Hence, the qualitative approach guarantees the richness of the data obtained in supporting the findings of the study.

iii) This approach has been found in my studies from other researchers in the development of mobile applications with low vision as their main subject such as Othman et al. (2020), Thakur et al. (2021), Ahmetovic et al. (2021) and Diskapama & Fauzi (2021).

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3.3 Triangulation Methodology

In qualitative research, triangulation refers to a full understanding of phenomena through the utilization of different methods or sources of data (Patton, 1999). Triangulation is also referred to as a qualitative research approach for testing validity by combining information from various sources. Triangulation is also defined as the act of combining many methods to investigate one trait to outline or descriptively explain the richness and complexity of human behaviour by examining it from multiple sources (Kennedy, 2009). From the perspective of the researcher, triangulation can be defined as utilizing more than one method or technique in the planned study to measure and investigate the problem of interest.

In general, triangulation is a method that is utilized by qualitative researchers. Triangulation is a strategy that qualitative researchers use to examine and confirm the validity of their studies by analysing a research topic from many perspectives (Guion et al., 2011). Moreover, triangulation is an effort to help in the study and explanation of complicated human behaviour by employing several methodologies to produce more balanced research findings. This is accomplished by the use of multiple methods to provide triangulation (Joppe, 2010). In addition, research on special needs education is frequently complex and places certain requirements on the methodology used (Ghesquière et al., 2004).

In the context of this study involves three parts: theoretical, developmental, and empirical which require process iteration. This study makes use of the Iterative Triangulation Methodology so that it can adhere to these requirements (Lewis, 1998). Figure 3.1 provides a visual representation of the triangulated data source and methods.

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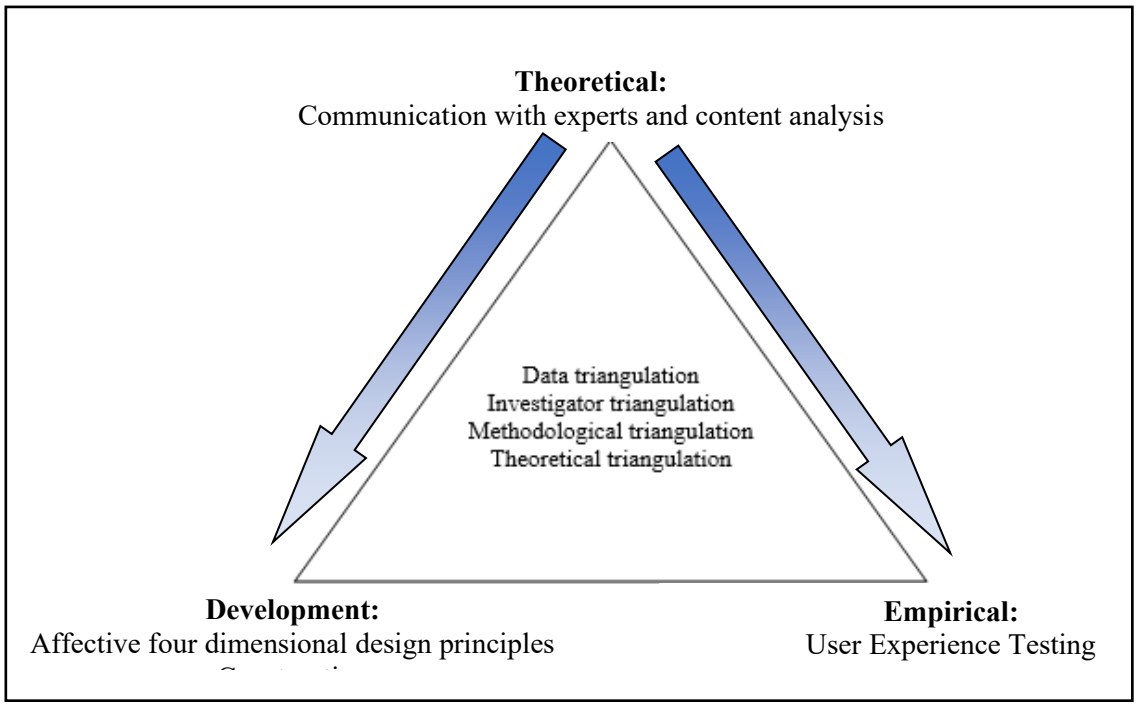

Figure 3.1 Data Iterative Triangulation Methodology

Denzin (1978) and Patton (1999) proposed four types of triangulations: (i) data triangulation, (ii) investigator triangulation, (iii) theory triangulation, and (iv) data source triangulation. The four types of triangulations describe as follows:

i) **Data triangulation**: Gathers data from different times, spaces, and persons.

- Time – involving two techniques to gather data; i) Cross-sectional and ii) Longitudinal. Cross–sectional allows researchers to compare many different variables at the same time. Meanwhile, longitudinal allow the researcher to conduct observations of the same subjects over a period. In this study, cross-sectional was applied by conducting semi-structured interview with different experts in a different areas, mathematics teachers from special need school, and experts with LV low vision, and the data were analysed at the same time. Meanwhile, for the longitudinal the prototype will be tested on a group of LV learners involved in repeated observations of the same variables until the results were saturated (Bowen, 2008)
- Space – the data will be gathered across multi- races of LV learners including Malay and Chinese.
- Person – the data gathered from different experts with different backgrounds such as mathematics teachers from different primary schools and experts in low vision.

ii) **Investigator triangulation** – During the observation session and interview session, there will be one observer and one interview respectively. However, the sessions also

will be well-equipped with the instruments both digital and non-digital instruments such as a video camera, audio recorder, and recording scheme used to record the data.

iii) **Methodological triangulation** – utilizing one or more than one method or strategy consisting of between-method and within-method to answer the research questions. Between-method is using different methods over the same samples to confirm the validity such as conducting observation and interviews over similar groups of LV learners. Meanwhile, the within-method is utilizing a similar set of interview questions at different times to test the reliability. For example, a semi-structured interview has been conducted before the actual testing is run to check the reliability of the semi-structured interview questions.

iv) **Theoretical triangulation** – seeking various theories to be used in this study to clarify the phenomenon from different sources and perspectives. This indicates that multiple theories of design principles and design guidelines have been incorporated as in Chapter 2.

According to Kennedy (2009), triangulation provides a more reliable approximation when each method of measurement agrees on the same answer. Triangulation is the most effective method for reducing bias in studies. This is the justification to employ a triangulation approach. The reason is that biased results in research results are introduced by error and no research methodology is completely devoid of error. Kennedy (2009) noted that relying on just a single method is to do with bias. It is on this basis that triangulation is necessary. Triangulation can help reduce several

common forms of bias in quantitative studies, including measurement or data bias, response bias, sampling bias, and procedural bias which can be minimized through triangulation. As an example, combining self-reported data with observational research could help strike a better balance. Researchers can mitigate the impact of sampling bias caused by their lack of access to a representative sample of the public by utilizing a combination of techniques, including mail, phone calls, and in-person meetings.

3.4 Rational of Using Triangulation Methodology

The following paragraph highlights the rationale for adopting the iterative Triangulation Methodology:

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i) To overcome depending on a single method which is related to business (Kennedy, 2009).

ii) To yield a more accurate and valid estimate of a result.

iii) To provide a complete purpose of the qualitative research by the in-depth understanding of the phenomenon under investigation by combining multiple methods and theories (Shih, 1998).

iv) The Iterative Triangulation Methodology also have been found adopted in other multimedia studies such as Ramli et al. (2017), Derlina et al. (2018), Hadi et al. (2018), and Isaacson (2020).

v) The method satisfies all the research phases and is relevant to the expected research outcomes of the study.

Consequently, the next subsection elaborates on the overall research process.

3.5 Phase in Methodology

Based on the above elaboration of the iteration parts involved in this study which are theoretical, development, and evaluation. To achieve the research objectives, a systematic task (Dwolatatzky et al., 2002) such design science approach (Peffers et al., 2007) which consists of five phases i) awareness of the problem, ii) suggestion, iii) construction, iv) evaluation, and v) conclusion will be employed in this study. Therefore, the rationale for using the design science approach has been highlighted in the next paragraph.

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i) Design science approach focuses on artifact development, to accommodate the design of practically useful artifacts (Peffers et al., 2018)

ii) Design science research contributes to the field of digital innovation by making both research and practice deployed in the development of artifacts (Hevner, 2019).

iii) As highlighted by Gregor and Hevner (2013), there are two dominant types of contribution elicited from design science research which are design theories and design artifacts. In the context of this study, the design theories are a new set of affective four

dimensional design principles specifically constructed for LV learners derived from the existing theories and design guidelines. Meanwhile, the design artifact is the fully working prototype for LV learners.

iv) Design science research yields to construct and arrange how to design things in obtaining knowledge and understanding desired set of goals (Hevner, 2019). For example, in catering to the problem of low vision learners in learning mathematics through the mobile application, the researcher involves the development and application of design science research of the design to the prototype.

All the highlighted rationales for adopting the design science research in this study are compatible with the research outcomes. This makes the adaption of design science research applies to this study.

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Hence, as mentioned earlier this study was implemented iteratively, and all phases interacting with each other during the study. As shown in Figure 3.2, the design science research phases are linked to the iterative Triangulation Methodology by three triangulated components (theoretical study, development, and empirical). The construction Affective Four Dimensional Design Principles are the focus of this study. Consequently, a series of actions is involved to achieve the goals specified in this study, although they are not executed in sequence due to the iterative nature of the process.

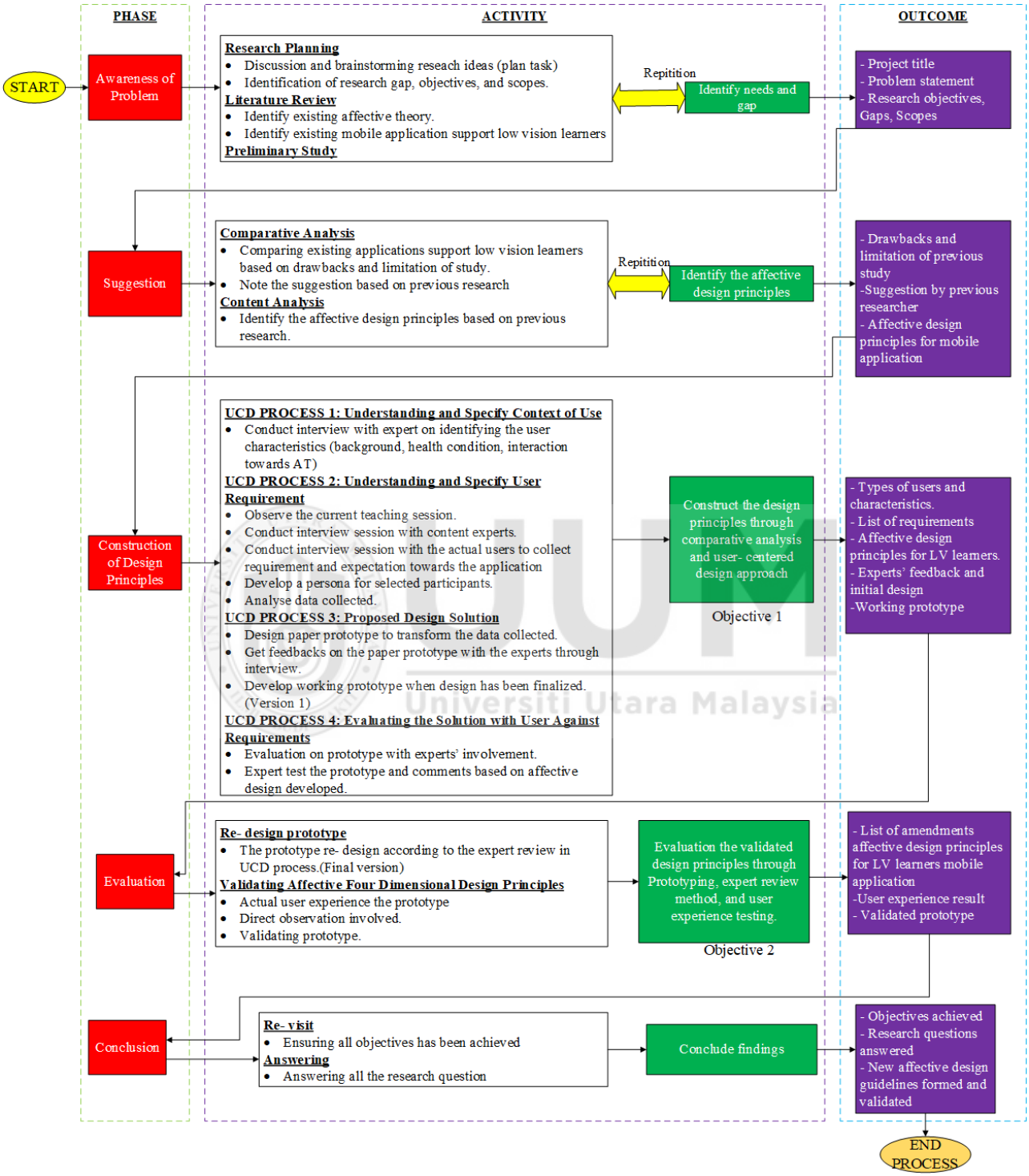

Figure 3.2 Phases in the Research Process

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3.5.1 Awareness of problem

In this study, the awareness of the problems is arisen through reviewing the literature review which led to the preliminary investigation with the experts. Several facts obtained from the literature review of the current articles along with the establishment of the actual data have led to the preliminary investigation. This resulted in the formulation of research objectives, gaps, and scopes as shown in Figure 3.3.

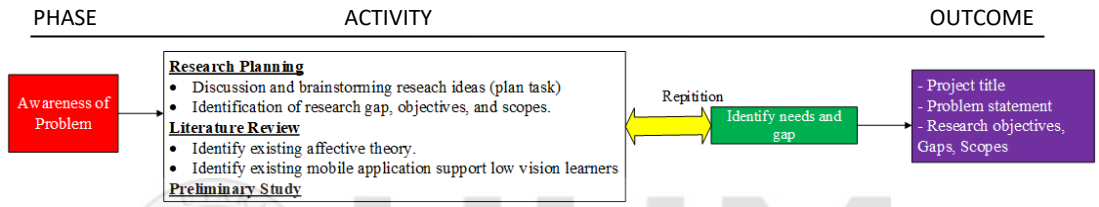

Figure 3.3 Awareness of The Problem Phase

i) Research Planning

In planning the research, a discussion and brainstorming idea have been done to organize the task for the research purpose. In this phase, the issues to be researched are defined through the elicitation from works of literature and preliminary interview with the experts. Few facts from the previous and current research including the collection of actual data have been identified that led to the preliminary interview. The identified literature review and preliminary interview have resulted in the establishment of the research objectives, gaps, and scopes as previously discusses in Chapter 1.

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ii) Literature Review and Preliminary Study with Experts

A literature study has been carried out through a comprehensive literature search through various databases to obtain information and facts including books, articles in journals, proceedings of international and national conferences, and newspapers. At this phase, ten existing mobile applications for visual impairment including LV learners were identified. The common issues of accessibility from the existing mobile application were identified and outlined in a form of a table.

Hence, this helps in understanding and acknowledging the current state of issues faced by the VI users based on the interfaces of the mobile application. Based on the gathered issues, two sessions of interviews were conducted to identify the availability and the needs of affective design for LV learners (Preliminary I) and to identify the background of the LV learners as the user (Preliminary II). Both findings of the initial studies are discussed in detail in Chapter 1.

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3.5.2 Suggestion

The second phase is a suggestion where the research problem, gap, and scope of this study have been identified. As illustrated in Figure 3.4, the drawbacks, and limitations of existing studies on the mobile application for LV learners have been compared and documented to compare the deficiency of existing design principles. The deficiency of existing design principles in accessibility issues has been outlined in the Table 1.3 in Chapter 1. The suggestion by the previous research has been noted down. The findings of this phase through reviewing the existing mobile applications and analysis of previous research have envisioned the new or existing elements of affective four

dimensional design principles to establish the relevant design guidelines for mobile mathematics applications for LV learners. All the elements were collected to develop an affective design principle.

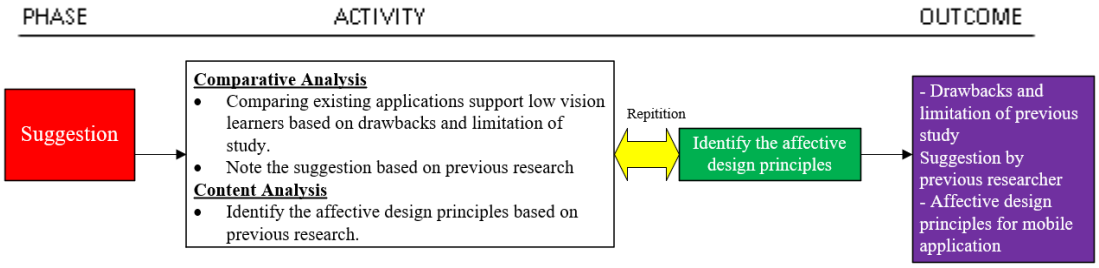

Figure 3.4 Suggestion Phase

i) Comparative Analysis

This study has explored, compared, and analysed two types of mobile applications that are different in their targeted users. The existing mobile applications are for Visually Impaired (both blind and LV) and LV users only. Each of the mobile application is illustrated in figures from their snapshots of applications. The drawbacks, limitations, and suggestions based on previous research of the study are extracted in a table. The results of comparative analysis from ten existing mobile applications were compiled and discussed in Chapter 4 in determining the elements of the proposed four dimensional component of (i) Emotion (ii) Feelings (iii) Thought (iv) Action in affective four dimensional design principles.

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ii) Content Analysis

The content analysis aims to organize and interprets the data obtained and to draw realistic conclusions from it (Bengtsson, 2016). The main aim of the content analysis is to identify the appropriate operational definition of the proposed four dimensional affective four dimensional design principles based on the previous emotional theories and definitions. The elements for the proposed four dimensional affective four dimensional design principles as well as the design principles were also identified based on the comprehensive review of ten existing mobile applications.

3.5.3 Construction

The construction phase is the third step in the DSRM process. It is concerned with the main contribution to the study which led to the accomplishment of the first objective outlined in this study. As illustrated in Figure 3.5, this phase aims to the construct of the affective four dimensional design principles, the mobile application for LV learners in learning mathematics. Then, the prototype was created by putting together the appropriate affective four dimensional design principles that were acquired during the comparative analysis process. Next, the prototype was validated through expert review. All the guidelines and elements were gathered to construct the affective four dimensional design principles.

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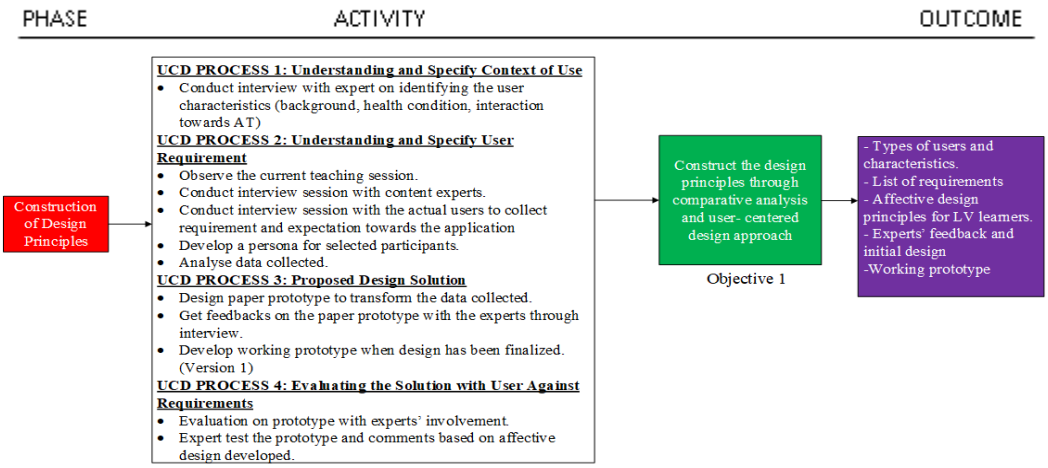

Figure 3.5 Construction phase

i) User-Centred Design (UCD) Approach

According to Vrendenburg et. al (2002) UCD is defined as UCD comprised of the active involvement of users in understanding the user and the task, iterative design and evaluation, and a multi-disciplinary approach. Generally, UCD approach is the process of developing of product to meet the user's needs. This approach fully attends to the user's requirements and limitations at every stage of the UCD process. The findings and comments obtained from the users were utilized for the design options and used for the development of the product. Thus, Abras et. al (2004) have outlined the advantages of applying the UCD in product development:

- **Products become more efficient, effective, and safe.**

The subjects who is LV learners are involved in every stage of the development process and have a deeper understanding between the subjects and the product. The involvement of the subjects assures that the product is developed following the intended purpose of which environment and end user.

- **Assists in managing users' expectations and levels of satisfaction with the product.**

The subjects are involved in the design of a product, they are aware that their thoughts and suggestion are taken into a consideration throughout the development of the mobile application. what to expect from the product from the beginning of the process, and they have the impression that their thoughts and suggestions have been taken into consideration throughout the process.

- **Users develop a sense of ownership of the product.**

The subjects sense what to expect to elicit from the product as they are involved in the initial process of development. This develops a sense of ownership and appreciation that product is created to cater to their special needs.

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- **Products require less redesign and integration into the environment more quickly.**

The involvement of subjects throughout the development process results in higher customers satisfaction with the mobile application and allows a smoother integration of the product into the environment (Preece et al., 2002).

- **The collaborative process generated more creative design solutions to problems.**

The comments and suggestions ideas were obtained from various perspectives of the subjects. This leads to more creative and effective design solutions to the problems.

Based on the outlined advantages shown that the UCD approach can satisfy the needs of LV learners in this study in applying an affective design for mobile application in mathematics subject. At this phase, four stages of UCD were conducted and the first UCD process has been conducted in Preliminary II. All the processes are planned and explained briefly in the next subsection.

ii) UCD Process

- **UCD Process 1: Understanding and Specify Context of Use**

This process has been done in Preliminary II which involves the interview with an expert in LV. The background of LV learners, health condition, and interaction with the AT has been noted in a semi-structured interview and been discussed in Chapter 1.

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- **UCD Process 2: Understanding and Specify User Requirements**

In this process, the actual user is involved in the process of determining the elements of the affective four dimensional design principles. The actual users are referred to as LV learners. Meanwhile, the experts are teachers among the selected school that provide special programs for LV learners. A piece of the form containing a list of findings on elements of affective four dimensional design principles was prepared for the LV learners and the teachers. The teachers give comments for each of the elements. The interview and discussion were held during the comment session simultaneously.

Then, the current teaching session has been observed. Meanwhile, an interview has been conducted with the LV learners to collect the user's expectations on their preferred elements for the application. The interviewees were labelled as "Subject" with a number to identify the participant sequences. For example, the first interviewee is coded as "Subject 1". This stage aims to analyse the data and establish common design principles or ideas that can inform a deeper understanding of related issues from the LV learners and the teachers. Hence, at this stage, the first objective which constructing the affective four dimensional design principles have achieved.

- **UCD Process 3: Proposed Design Solution**

The data from the previous stage was transformed into a paper prototype. The design is illustrated according to comparative analysis and interview sessions with the actual users and the experts. At this stage, feedback is obtained from the experts through interviews. This study develops a specific instrument for evaluating the affective four dimensional design principles. In the instrument, the elements are derived from the operational definition of the proposed four Dimensional design principles. The language and the constructions of the items are validated according to LV learners' preferences. Then, the elements are determined whether not relevant, maybe not relevant, and all relevant to the study. The instrument asks about each element in the mobile application. Through the review, the comments and suggestions were noted down, and the instrument is revised. This review form was purposely developed by the researcher to validate and revise each element in the affective four dimensional design principles (draft version). When the design has been finalized and the purpose of proving the concept, a working prototype (draft version) is developed.

- **UCD Process 4: Evaluating the Solution with User Against Requirements**

The working prototype was evaluated by the experts to improve the quality of the work. The experts involved in this stage academicians from local universities who have been at least five years of experience in their field. At this stage, the proposed elements, design principles, terms used, and the logical connections and flows of all components were taken into consideration. The readability of the working prototype is considered by the experts.

A piece the instrument was given to the experts to review and annotate helpful comments to improve the proposed design. The process of evaluating the prototype was conducted through emailing services. All the comments from the experts were justified, and this study is coming out with a reviewed affective four dimensional design principles which ready for prototyping as discussed in the evaluation phase.

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3.5.4 Evaluation

Based on Figure 3.6, the evaluation is carried out to validate the applicability of the prototype using an expert review method, prototyping, and user experience testing. Actual user testing was conducted to test the user's acceptance of the prototype, which applies the affective principles for LV learners in learning mathematics. This phase resulted in the achievement of the second objective.

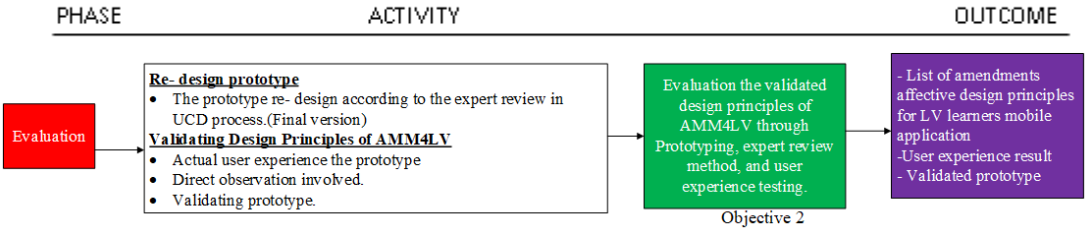

Figure 3.6 Evaluation Phase

i) Redesign Prototype

The design re-design according to the comments and suggestions of the experts from the previous UCD process. Then, the prototype (final version) is ready to be tested with the actual user after being validated through the expert review method, prototyping, and user experience testing.

ii) Validating Design Principles

The actual user experiences the prototype. Direct observation was involved during the user testing session. The selection of evaluation methods must match appropriately in line with the research outcomes. In conjunction, the following subsection discusses the sampling, strategies, and instruments involved in this study.

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iii) Sampling and Sample Size

This study utilized purposive sampling as the subjects in this study selected share specific characteristics which means the subjects are homogeneous (Teddlie & Yu, 2007). The specific characteristic that is focused on in this study is subjected to the LV learners from standard one until six from special needs schools. Purposive sampling tends to focus on the selected subject to enable the study to answer the research questions (Battaglia, 2008).

Qualitative researchers frequently use small sample sizes for a better understanding of how theories and psychological constructs apply in real-world settings (Pratt, 2009). Small sample sizes are intended to assist qualitative researchers to acquire rich results

with a smaller number of participants (Jonsen et al., 2018). In this study, the sample was composed of seven subjects from one special needs school. The subjects were involved from the beginning of the process of observation and interview until the process of validating the working prototype through user experience testing. Although the quantity of the sample is limited, however, they are sufficient to respond to the research question. As noted by Sandelowski (1995), if the research purpose is to understand a specific phenomenon one case may be sufficient for the research sample.

iv) User Experience Testing

The next part involves user experience testing. This study evaluated four dimensions (i) Emotion (ii) Feelings (iii) Thought and (iv) Action. These four dimensions were selected based on the needs of LV learners that have been clarified in Chapter 1 and Chapter 2. Hence, the purpose of the evaluation is to obtain validation on those selected dimensions and whether the provided affective four dimensional design principles based on the four dimensional elements are useful to the LV learners. This study decides to apply observation and interview as methods in gathering the data during user experience testing.

The user experience was conducted in a classroom where the subjects were equipped with a tablet the application has been installed on each of the tablets. Due to the limitation of the tablet, the observation needs to be scheduled to be limited to two subjects per session. The subjects were arranged to sit next to their peers according to the arrangement in their routine class. This makes them feel comfortable throughout

the observation process as their behaviour and interaction towards the prototype are highly valuable during this user experience testing process.

v) Data Collection Method

This study collected the data in two methods (i) Observation and (ii) Interview. They are discussed in the next subsections.

- **Observation**

In this study, an observation was conducted to help in clarifying the affective four dimensional design principles that affect the player's emotions, feelings, thoughts, and actions. The users can provide their feedback after the user testing session. Non-participant observation was used in this study because of the nature of the participants. Non-participant observer observes without any involvement in human interaction in the field (Ciesielska et al., 2018). The testing session was conducted in their regular class setting. In this study, structured observation is utilized. A structured coding scheme contains the setting of the subject, timeline, and states of the subject during the observation.

i) Observation Instrument

The observation instrument used in this study adopted the scene coding scheme from Ng et. al (2018) study. The scene coding scheme can aid the researcher in recording the user's emotions and behaviour (states) interacting with the scene in the mobile application. The observation was recorded in two forms: scene and state. There were

scenes or activities subjects were likely to carry out in the mobile application. States are the subjects' reactions during the interaction and what triggered them to react that way. However, the main focus of this observation is to focus on the clarification of the affective four dimensional design principles based on the emotional states and action of the subjects.

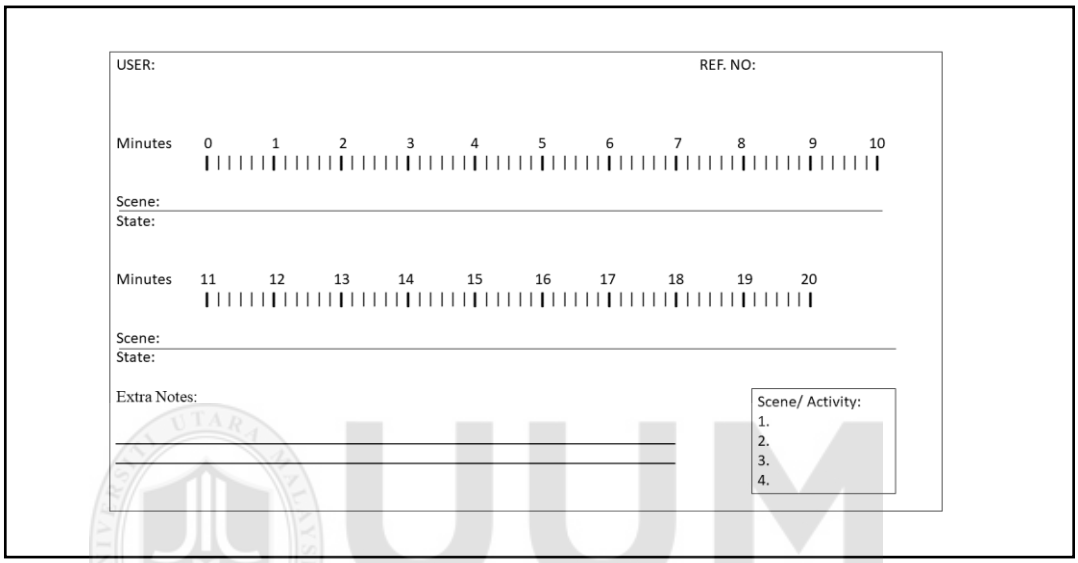

Figure 3.7 Scene Coding Scheme

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Based on the Figure 3.7, the emotional states of subject were recorded within the twenty minutes length of user interaction towards the prototype. The emotional state and action were jot down. Currently, there are numerous instruments are applicable in recording the observations. However, despite recording the data on the spot using the scene coding scheme to avoid throwing the valuable data, the researcher prepares the following instruments as described in Table 3.1.

Table 3.1

List of Interview Instruments

Instrument	Description
Video recording	Video recording is important in analysing the data in detail after the observation session is finished. The recording will assist the researcher to replay the unrecorded or missed data

	from the scene coding sheets. This study will be utilizing camera video to record.
Audio recording	The audio recording is parallelly recorded using the same instrument of camera video. This is very important to measure the thoughts of the subjects through their verbal communication while interacting with the prototype
Screen recording	This study will utilize a screen recorder application during the use of the prototype to capture the activity process of the subjects.

- **Interview**

A set of structured interview questions was prepared before the interview (Appendix H). However, to accommodate the LV learners who participated in this research, the questions that were asked during the interview sessions were modified to align with their responses. The interview was conducted after the subjects view the prototype. The experimental group that was participating in the observation was also given the same set of questionnaires. During the last session of the interview, the participants will be allowed to provide their feedback by providing their views and suggestions in response to an open-ended question in the questionnaires.

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- **Interview Instrument**

The interview sessions were recorded using an audio instrument. This assists the study to evaluate the data after the interview ends. The next subsections will discuss the techniques to analyse the data obtained.

vi) Analysis of User Experience

This study analysed the findings of empirical evidence through the analysis of an expert review.

a) Analysing Interview Data

In analysing the data from the interviews and observation, the recorded data were transcripted. Each of the transcript data was reviewed and noted down thoroughly to take note of the views, perceptions, and states of the low vision regarding the usefulness of the prototype. The qualitative data were managed and analysed manually. The text data will be grouped, organized, and read to figure out the key findings and the theme (Khadka et al., 2012). The theme is based on the affective Four Dimensional components proposed in this study.

According to Walsh et al. (2008), to verify any topic as a theme (in this study refer to items derived based on the affective Four Dimensional components) the theme must fulfil two of the criteria: i) at least two subjects from the selected participants' comments on that topic, and ii) at least one subject from two different groups discussed the similar topic. The gathered data were recorded and reviewed by the experts.

- **Expert Validation**

The prototype is verified by expert. The review session is aimed to verify the use of affective four dimensional design principle for LV learners in the prototype (final version). Similar experts were involved during the review session.

In the session, the experts were provided with the working prototype (final version) and they are acquired to check whether the mandatory elements are successfully embedded into the developed prototype. During the verification session, the researcher as the developer is responsible to acknowledge the elements of affective four

dimensional design principles located in the prototype. All the comments and suggestions were noted during the session. Table 3.2 shows the evaluation form for expert review.

Table 3.2

Expert Review Evaluation Form (Final Version)

Items		Affective four dimensional design principles	States	Expert Comment
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

vii) Research Procedures

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Prior to the data collection process, the permissions were secured for the expert evaluation and real experimentation phase of the study. Permission for expert review was obtained from selected reviewers, while permissions for the real experimental study were obtained from the Special Needs Education Department using the ERAS 2.0 application. Due to the pandemic, COVID- 19 obtaining permission to conduct research in a school must be made through the application first before obtaining internal permission from the headmasters at each of the selected schools.

3.5.5 Conclusion

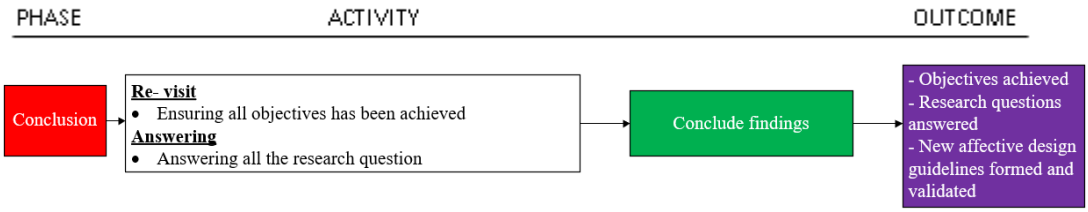

Figure 3.8 Conclusion Phase

The final phase in DSRM is to bring the study to a conclusion. The study ends with revisiting the research question and research objectives. All the main objectives have been accomplished.

3.6 Summary

The methodology that was employed to achieve the research objectives is discussed in this chapter. The research design is explained in detail to provide a comprehensive understanding of how this study was initially conceived and executed, as well as the processes that were followed throughout the design phase. Iterative Triangulation Methodology has been adopted in this study involving three major parts: theoretical, development, and evaluation. All the parts require an iteration process. To achieve the outline objectives, a systematic plan implemented through the five phases from design science research which are (i) awareness of the problem, (ii) suggestion, (iii) development, (iv) evaluation, and (v)conclusion was adapted.

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CHAPTER FOUR

CONSTRUCTION OF AFFECTIVE FOUR DIMENSIONAL DESIGN PRINCIPLES

4.1 Overview

This chapter describes affective four dimensional design principles. Content analysis, comparative analysis, expert review, prototyping, and user experience testing are used to establish the proposed affective four dimensional design principles. The role of experts in verifying the proposed model is also discussed in detail. The relationship between the techniques and objectives is illustrated in Figure 4.1.

Method	Objective	Outcome
Comparative Analysis	• To compare existing applications support low vision learners based on drawbacks and limitations of the study • Take note on the suggestion based on previous research	• Justification of 10 existing mobile application for low vision users. • Element and design principles based on previous studies
Content Analysis	• To identify affective design principles based on previous research	• Components, elements and design principles based on analyzed design principles.
Expert and Actual Users Experience	• To construct the design principles through comparative analysis and user-centered approach	• Proposed components, elements and design principles.
Expert Review	• To evaluate the validated design principles through expert review method, prototyping and user experience testing	• Reviewed and validated affective design principles

Figure 4.1 Summary of Activities in Constructing Design Principles

The affective four dimensional design principles extend the idea of established design principles to build a mobile application. This study addresses affective characteristics, making it different from other mobile application. As mentioned in Chapter 1, most mobile application does not accommodate LV learners. As described in Chapter 2, this study discovered acceptable affective four dimensional design principles based on assistive mobile application design guidelines. These features are needed to meet the needs of LV learners, as identified through literature analysis, comparative analysis, and UCD approach supported by expert and actual user experience testing. Their characteristics are detailed in Figure 4.2 and Table 4.1 justifies the UCD selection criterion.

Table 4.1

Criteria and Justification of Participants in UCD Cycles in the Construction of Design Principles

Users	Criteria	Justification
Low vision learners	Their school level is from standard two until standard six with an average age of nine to five years of experience.	LV learners are the target users . They are learning by the means of ICT since standard one. Involving them is crucial to figure out the specific affective elements and principles of the proposed design principles to cater to their needs in learning.
Teachers	They have been teaching LV learners for at least five years and above.	Five years of experience in teaching LV learners could increase the confidence of this study to seek and confirm the needs of LV learners in their learning activities.
Academicians/ Researchers	Their criteria are discussed in Figure 4.2	Their participation is to review, comment, and validate the proposed design principles.

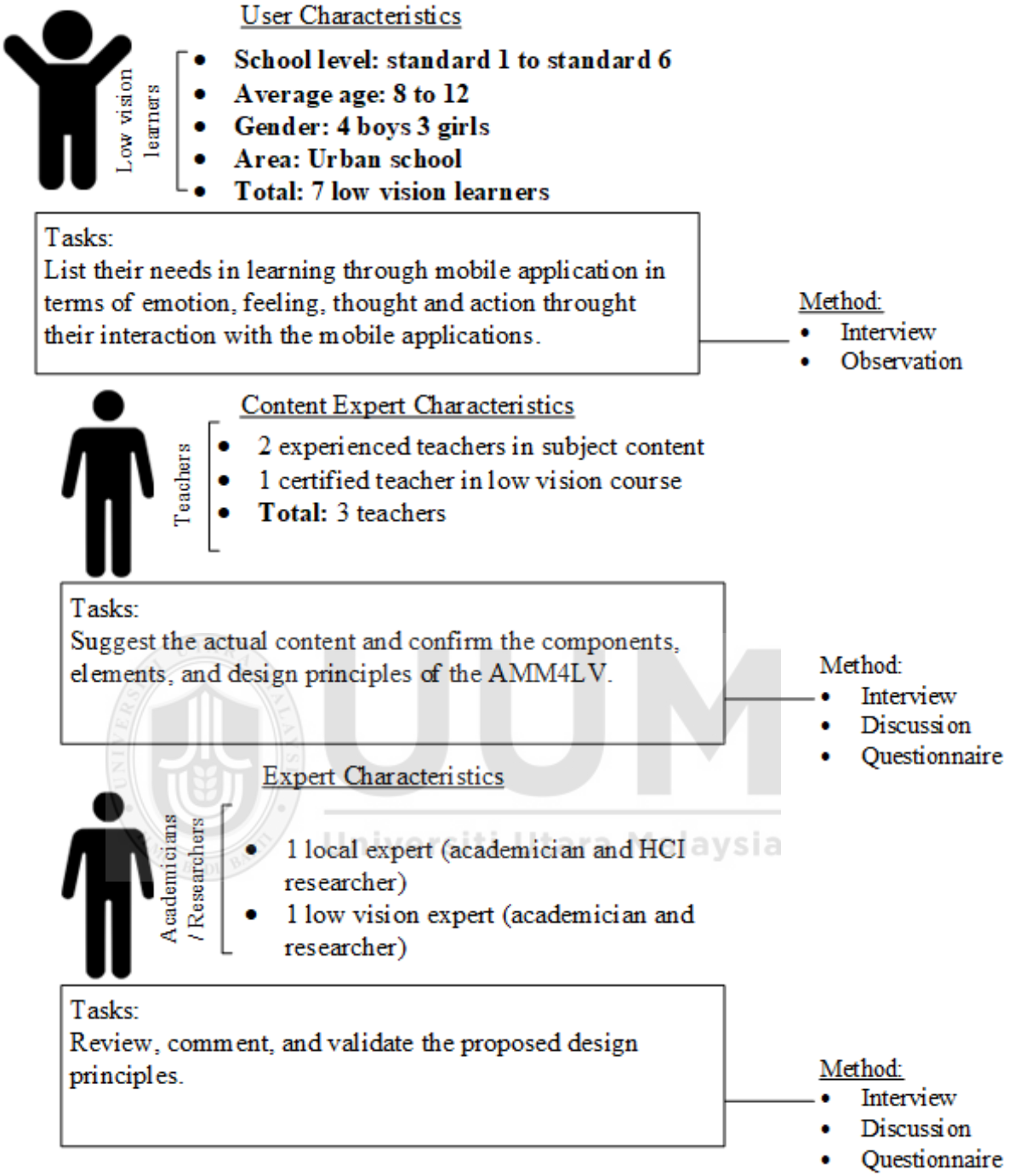

Figure 4.2 Summary of the Participants in UCD Cycles in the Construction of Design Principles

This study leverages affective design to make the mobile learning software accessible and learnable for LV learners. The affective four dimensional design principles are derived from the main component of emotion, feeling, thought, and action of the low

vision learners. Accordingly, it leads to the idea of determining the design principles through the components which are then applied in the content design.

In short, the proposed design principles incorporated particular attention to emotion based on the components, which fulfil the needs of LV learners. This is called affective four dimensional design principles. The remaining parts, which detailed the affective four dimensional design principles are elaborated properly.

4.2 Component of Proposed Design Principles

Prior to proposing the design principles , an analysis of the operational definition of the affective four dimensional design principles were conducted. The affective four dimensional design principles were derived from the operational definition of the main component of four dimensional design principles.

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A comparative study also conducted on ten mobile applications from the previous study. These mobile applications were chosen because they are considered based on mobile applications for people who are visually impaired. With the interest of identifying where the research gap is, this selected assistive mobile application has been dissected and examined thoroughly including its shortcomings. Consequently, this section compares them intending to identify the affective four dimensional design principles based on the four dimensional components. They were selected to compare based on the justifications detailed in Table 4.2.

Table 4.2

Justification for Selected Four Dimensional Components

No.	Components	Justification	Elements
Emotion		It defined emotion on many levels one of the levels is memory (Derryberry & Tucker, 1994)	Memorable
		Emotion is effective in providing retrieval cues for long-term memory (Isen et. al, 1987).	
		Emotion is defined as it is tightly related to memory where it influences one's attention and how one remembers things (Coetzer, 2017).	
		Emotion is revealed to contribute to learning motivation (Katai, 2020).	Motivational
	Feeling		
5.	Tomkins (1963)	Positive emotional states are interest and happiness.	Interest
6.	Mehrabian (1972)	Emotional states influenced learners' interest in the educational setting.	
7.	Demirbilek and Sener (2003)	Categorized sense as types of happiness.	Happiness
8.	Shedroff (1994)	Suggested that sense is a response to communicate with others.	
9.	Shedroff (1999)	Added to include sensorial design to deliver content to understand human senses.	
	Thought		
10.	Norman (2005)	Stated human brain works on three levels; one of the levels is visceral (perceptually based). Visceral design provokes a quick and powerful perception between the user and the product.	Positive Perception
11.	Mueller (2004)	The user is triggered by the appearance.	
12.	Mather and Sutherland (2011)	Emotion is affected by perception.	
13.	Shirke et al. (2020)	Emotion is referred to as a natural instinctive state of mind triggered by certain circumstances and moods. Different emotion leads to a	Positive Mind State

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		different state of mind caused by internal or external stimuli or events.	
	Action		
14.	Coetzer (2017)	Ease of navigation may result in a feeling of satisfaction when interacting with the application.	Navigation
15.	Shamsuddin et al. (2011)	Interaction by action-based can improve user's learnability and understandability.	
16.	Mueller and Lockerd (2001)	User interactions on a system indicate users' interest.	Interaction
17.	Evans and Gibbons (2007)	Classified users' interaction to student-to-content interaction that allows users to control the application and receive feedback.	

Regarding Table 4.2, the items were derived from the operational definition of each of the components which produced the proposed affective design guidelines. Accordingly in determining the design principles for the proposed design principles a comparative analysis has been done on the existing mobile application for the visual impaired. This comparative analysis is of the utmost importance to guarantee that the proposed model is constructed based on the established root. The snapshots of mobile applications and the subsequent elaboration on those snapshots were used in the analysis. The limitations and suggestions discussed in Chapter 2 are recorded.

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4.3 The Proposed Affective Four Dimensional Design Principles

The components are relevant to the content. Each of the proposed design principles is determined by the objects and is supported by its justification. As stated in Chapter 2, they are developed in accordance with accessibility guidelines, design guidelines for children, and literature reviews from prior studies. It also includes expert consultation using the UCD approach. Their comments are consistent with early discussions on

affective and accessibility as presented in Chapters 1 and 2. Before designing design concepts, it is essential to ensure that the proposed elements closely cater to the needs of LV learners. Each of the proposed affective four dimensional design principles has its connection with the four dimensional components, as shown in Table 4.3.

Table 4.3

Proposed Affective Four Dmensional Design Principles

Four Dimensional Components	Elements	Affective four dimensional design principles
Emotion	i) Memorable	1. Provide consistency in design by using similar graphical elements such as buttons, and icons for LV to and memorize the gesture throughout the navigation process of the mobile application. LV learners need not relearn the gesture every time they use the mobile application.
	ii) Motivational	2. Create a good colour contrast between background and foreground to motivate the LV learners to prolong the use of the mobile application. Low colour contrast is a barrier for LV learners to operate the mobile application.
Feelings	i) Interest	3. Provide a clear and symmetrical layout to inculcate a pleasant experience that can generate interest in LV learners. A balanced design requires less attention from LV learners to analyse the design due to their eye limitations. 4. Use landscape orientation to increase the text size and space when LV learners view the content.
	ii) Happiness	5. Imitates children's voice intonation to deliver the instructions to the LV learners. This is corresponding to the voice principle in Design Guideline for

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		Children (2007). This can increase the engagement between the LV learners and the contents. 6. Includes human character as an attraction to increase the sense of humour interacting with the contents for LV learners according to Multimedia Learning Theory (2001)
Thought	i) Positive perception	7. Provide name labelling for each button. LV users have a better experience because the labels that they hear match the visible text labels that they see on the screen. This gives a positive perception of delivering the visual content to the LV learners.
	ii) Positive mind state	8. Use the biggest text font size for LV learners 18pt and sans serif fonts to form a perceptible appearance of the multimedia elements to the LV learners to encourage a positive mental state of LV learners. 9. Use a high contrast of interface components (non-text components) such as buttons, icons, and images against the background. Increasing the clarity and contrast of functional buttons can clarify the LV learners on how to perform in the contents.
Action	i) Navigation	10. Place the button at the edge of the application so it is more reachable to the LV learners.
	ii) Interaction	11. Provide feedback to make the interaction of LV learners clearer as to what action is needed and has been accomplished. This addresses the action needed for the LV learners to what to practice and avoid. 12. Provide error handling to acknowledge LV learner's action of navigation such as the back/ undo button.

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4.4 Expert Review

Expert review is a popular heuristic evaluation method for system or application usability issues. To confirm and validate research field usability concerns like navigation, functionality, efficiency, and affectiveness of products. Experts were chosen based on research expertise. According to Ishaq et al. (2021), three to five experts can identify usability concerns in application reviews. Table 4.4 lists expert information.

Table 4.4

Experts Profile and Demographics

Expert	Gender	Position	Academic Background	Years of Experiences
A	Male	Associate Professor	Doctor of Philosophy in Human-Computer Interaction	15
B	Male	Associate Professor	Doctor of Philosophy in Optometry	14
C	Male	Teacher	Bachelor of Education	10
D	Male	Teacher	Bachelor of Education	7
E	Female	Teacher	Bachelor of Education	8

Table 4.4 shows that two academics and three practitioners participated in this review. A is a human-computer interaction (HCI) scholar, while B is a LV associate lecturer. LV professionals with PhDs in IT, multimedia, and HCI. Practitioners are teachers with a bachelor's degree in education for Disabilities and more than 10 years of experience.

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4.4.1 Instrument and Procedure

Throughout the review, process email was used as the medium of communication. First, an invitation email was sent to the identified experts. A sample of the invitation emails is attached in Appendix A. Having agreed to be appointed as an expert reviewer, a consent form (Appendix B) and an official appointment letter (Appendix C) were sent to them. The signed and stamped consent form was emailed with the instrument. The experts had ample time to analyse the design ideas and complete the questionnaire. Most completed all tasks in two to three weeks.

The proposed affective four dimensional design principles checklist is the primary instrument utilized for expert review. In addition, a few demographic questions, such as the number of years of professional experience and the highest degree of education attained, were posed to the experts. Along with that, they were also encouraged to submit their further comments on the instrument that was provided to them. The first question featured a list of the proposed components, and the experts were asked to verify the relevancy of the elements that were contained by the components (i.e. definitely not understandable, are not relevant, or all are understandable). The format of the questionnaire is adapted from Siti Mahfuzah (2011). Table 4.5 shows the instrument for the expert review of the proposed affective four dimensional design principles.

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Table 4.5

Proposed Affective Four Dimensional Design Principles Checklist

1.	The proposed items in the following components are relevant	Definitely not understandable	Maybe not understandable	All are understandable	Remarks
	Emotion:				
	i) Memorable				
	ii) Motivational				
	Feelings:				
	i) Interest				
	ii) Happiness				
	Thought:				
	i) Positive Perception				
	ii) Positive Mind State				
	Action:				
	i) Navigation				
	ii) Interaction				

2.	The proposed design principles are understandable	Definitely not understandable	Maybe not understandable	Understandable	Remarks
	1. Consistency in design to memorise the gesture				
	2. Create a good colour contrast between background and foreground to motivate the learners				
	3. Provide a clear and symmetrical layout to inculcate pleasant experience				
	4. Use landscape orientation as their preferred orientation				
	5. Imitates children voice intonation to engage with the learners				

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	6. Includes human character as attraction to increase humour interaction				
	7. Provide name labelling for button for LV learners to have positive perception delivering visual content				
	8. Use the biggest text fonts 18pt and sans serif to form a perceptible appearance to encourage positive mind state				
	9. Use highly contrast interface components to clarify the LV to perform the contents				
	10. Use non-linear navigation to minimize the navigation path				
	11. Place button at the edge of application				
	12. Provide feedback to address the action needed and have been accomplished				
	13. Provide error handling to acknowledge LV learners' action such as back/ undo button				

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4.4.2 Expert Review Findings

The gathered data were recorded in Table 4.6 based on the questions asked in the instrument.

Table 4.6

Responses from Expert Review

Items	Frequency (n=5)		
	Definitely not understandable	Maybe not understandable	Understandable
Q1 The proposed items in the following components are relevant			
i) Memorable	-	-	**5**
ii) Motivational	-	-	**5**
iii) Interest	-	-	**5**
iv) Happiness	-	-	**5**
v) Positive Perception	-	-	**5**
vi) Positive Mind State	-	-	**5**
vii) Navigation	-	-	**5**
viii) Interaction	-	-	**5**
Q2 The proposed design principles are understandable			
1. Consistency in design to memorise the gesture	-	-	**5**
2. Create a good colour contrast between background and foreground to motivate the learners	-	1	**4**
3. Provide a clear and symmetrical layout to inculcate pleasant experience	-	-	**5**
4. Use landscape orientation as their preferred orientation	-	-	**5**
5. Imitates children voice intonation to engage with the learners	-	-	**5**
6. Includes human character as attraction to increase humour interaction	-	-	**5**

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7. Provide name labelling for button for LV learners to have positive perception delivering visual content	-	-	**5**
8. Use the biggest text fonts 18pt and sans serif to form a perceptible appearance to encourage positive mind state	-	-	**5**
9. Use highly contrast interface components to clarify the LV to perform the contents	-	**1**	**4**
10. Use non-linear navigation to minimize the navigation path	-	-	**5**
11. Place button at the edge of application	-	-	**5**
12. Provide feedback to address the action needed and have been accomplished	-	-	**5**
13. Provide error handling to acknowledge LV learners' action such as back/ undo button	-	-	**5**

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As exhibited in Table 4.6, most of the experts agreed that most of the proposed design principles are understandable. However, Expert C disagrees with the colour contrast between background and foreground to motivate the learners chose as it might be not suitable for the degrees of low vision learners. Meanwhile. other experts agree on the colour contrast.

Expert B opposes button name labelling design concepts. This is because the labelling is labelled with two words which later might be not fully readable by the low vision learners. Expert B said words must be clear. This study reduces button labels from "Ulang Semula" to "Ulang". A, D, and E agree on all design principles. Expert A additionally suggests noting the design guidelines for the mobile application's interface, including colours, buttons, characters, and content.

4.5 Summary

This chapter explains the activities involved in constructing the design principles . It starts with defining the main components of four dimensional to derive the items for affective four dimensional design principles. It is followed by noting the desired component and elements of ten existing assistive mobile applications for visual impairment through their discussion and suggestion from their studies. It is combined the previous with analysing the previous related works of literature. From then on, special features named affective four dimensional design principles were derived. These affective four dimensional design principles are expected to support the needs of LV learners by applying the affective element based on the four dimensional component. This outcome serves to support the first objective of this study. In addition, the expert review method also has been carried out to validate the propose affective four dimensional design principles. Hence, a revised affective four dimensional design principles was formed. The detail of this has been explained in Chapter 5. Later, a comprehensive user experience testing procedure was conducted which is described in Chapter 6.

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CHAPTER FIVE

PROTOTYPING DESIGN PRINCIPLES

5.1 Overview

The procedures followed to construct the affective four dimensional design principles were outlined in the preceding chapter. Detailed consideration was given in defining the four dimensional components and comparing the existing mobile applications to determine the intended affective four dimensional design principles . The proposed affective four dimensional design principles were also developed after extensive research and consultation with experts and target users to guarantee they would fulfil their needs. Then, all the components and items were merged as affective four dimensional design principles reviewed by five experts. As a result, the affective four dimensional design principles were proposed.

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The proposed affective four dimensional design principles were verified through prototyping to move on to the second objective of this study. This interprets that, to ensure that the proposed affective four dimensional design principles are useful, they must be translated into a working prototype. The successful development of a prototype demonstrates that the recommended affective four dimensional design principles have been validated after this milestone has been reached. So, the process of creating and developing the prototype is carried out in accordance with the affective four dimensional design principles that have been proposed. This study is named as AMM4LV.

The subsequent section provides a full discussion regarding the development process of the AMM4LV, which is then followed by the prototype of the AMM4LV that emerged with the affective four dimensional design principles.

5.2 The Development of AMM4LV

Non-technical or novice developers who are interested in creating AMM4LV are encouraged to follow the design principles guideline suggested in this study. This means that anyone can create AMM4LV using any method or appropriate software. The content is also up to their preferences. If the developer is a teacher, their course-related knowledge is valuable. This makes product development easier, even though cost and quality must be considered. Yet, they must follow the affective four dimensional design principles and proposed items. Non-technical developers should follow the development method outlined in the proposed affective four dimensional design principles.

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This study explores the fundamental processes that are typically necessary when designing applications for multimedia platforms. Pre-production, production, and post-production are the three stages that make up the entirety of the process. The majority of the steps need to refer based on the essential components that have been proposed in this study. These are discussed in further depth in the sections that follow.

5.2.1 Pre-production phase

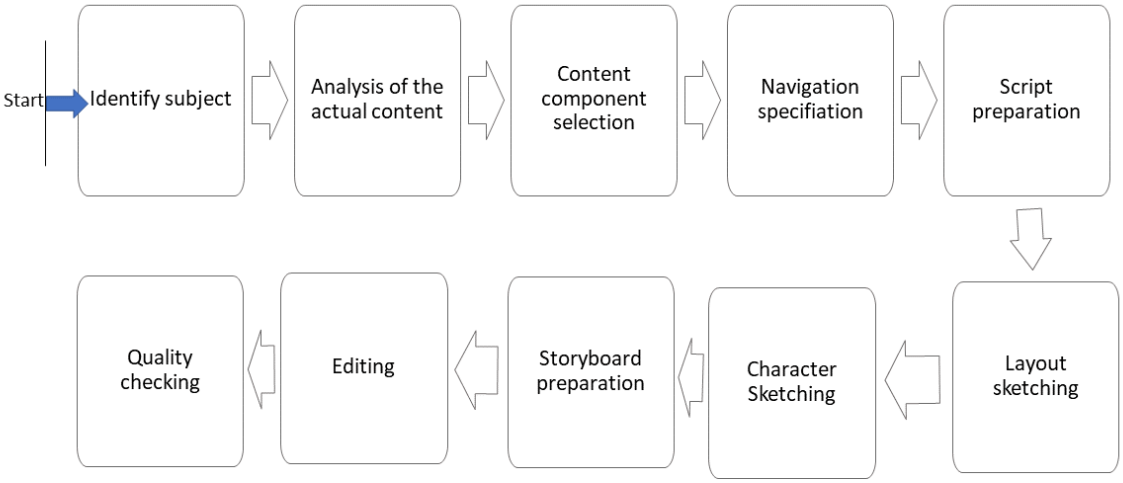

Figure 5.1 Pre-production Phase

i) Identify Subject

First, the researcher conducts an observation in a classroom to see their learning process to identify the learning style and gadgets used in their learning process by the means of technology. Additionally, input from teachers suggest on the topic from the mathematics subject to be selected for the AMM4LV which is "Multiply". This is because most of the explanations for this topic the LV learners need extra elaboration by watching the video and enhancing their understanding by answering the online quiz. The subtopic suggested by the teachers requires lots of illustrations that the existing explanation video is hard to be learned by the LV learners.

ii) Analysis of the actual content

The steps involved in this phase are (i) analysing the topic and activities, (ii) Organising the relationship between the topic concept and activities, and (iii) analysing the appropriate form of activities. This was carried out by referring to

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the textbook and discussion from the low vision learners with their teachers as they are the expert content.

iii) Content Component Selection

By referring to the proposed design components, this AMM4LV is built based on the Four Dimensional components for affective four dimensional design principles to be embedded into the interface of this AMM4LV.

iv) Navigation Specification

The researcher must follow the navigational button and interface layout design concepts to make AMM4LV easy to navigate. Non-linear topic concept and activity navigation. Figure 5.2 shows AMM4LV navigation.

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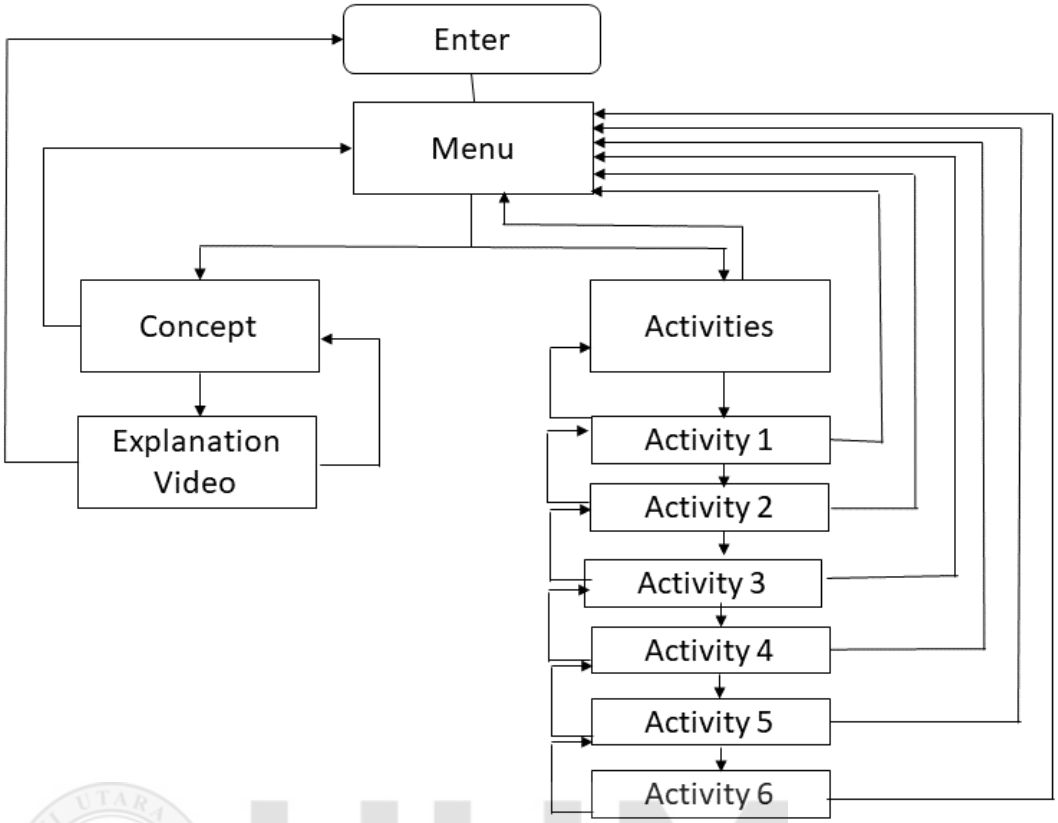

Figure 5.2 Navigation Flow in AMM4LV

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Figure 5.2 shows the flexibility of navigation in AMM4LV. Users can choose any action during the learning process. Figure 5.2 shows the navigation specifications that the mare can easily access. After learning the topic, they should do the exercise. They can also return to the main menu to recall the main concept of the subject. In summary, AMM4LV offers dynamic navigation flexibility to engage LV learners with the mobile application.

v) Script preparation

Following the completion of the navigation flow, the scripts were produced in accordance with the inputs obtained from the previous phase. The script was very crucial to keep track of all the elements in the show. The few steps are depending on this step of script preparation. Since the users are LV learners, the scripts must adhere to the design principles and content components . The script has been prepared in Appendix D.

vi) Layout Sketching

The researcher sketches the layout after writing the script. The researcher must follow the affective four dimensional design principles for interface and interaction.

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vii) Character sketching

Once the actual content has been identified and the scripts have been prepared, it is time to sketch the character. In this study, one-character acting as a peer called "Alisya" was created. The character is a girl from a primary school. This character chooses to create the learning process by peer-teaching.

viii) Storyboard Preparation

The storyboard (available in Appendix E) was designed based on the layout sketching, at this stage, the developer has identified all the graphics, texts, audio, and navigational button were determined.

ix) Editing

In this study, the editing process was performed especially on navigation, scripts, and storyboard parts. Again, the proposed affective design principle was referred.

x) Quality Checking

The final pre-production step involves quality-checking all materials. The researcher developed the application and quality-checked it with teachers and academic experts in this study. The teacher and academic expert listed flaws throughout the discussion. All pre-production materials were ready for the production phase.

5.2.2 Production Phase

The production phase has nine steps. At this stage, AMM4LV development started. 'Expo' a developer tool was used to create the AMM4LV. Figure 5.3 shows that steps one to three can start simultaneously. This reduces production time.

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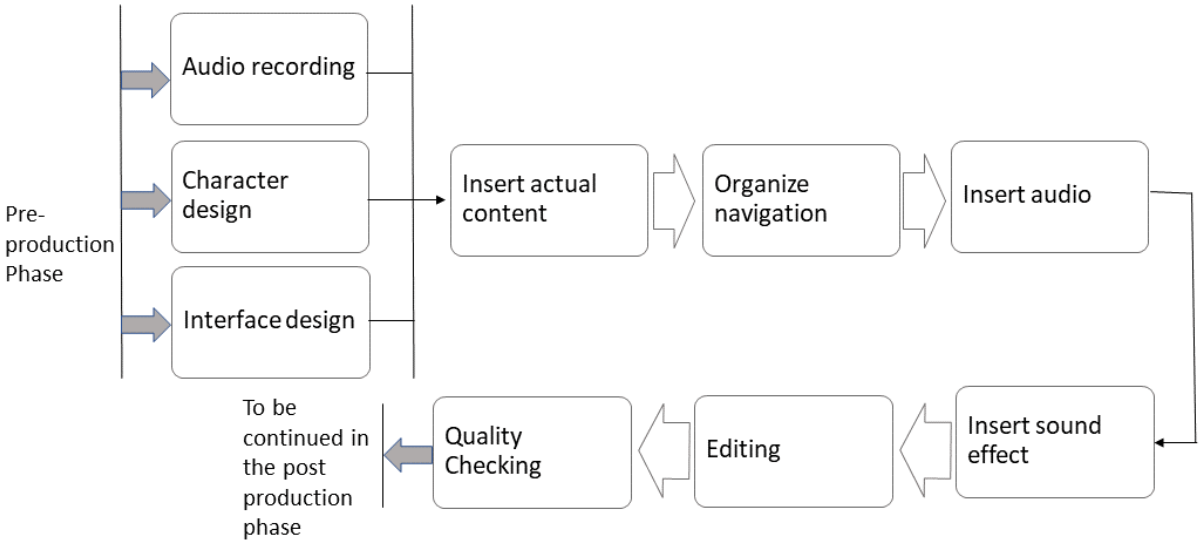

Figure 5.3 Production Phase

i. Audio recording

The scripts prepared in the pre-production were recorded. LV relies solely on audio; the recording speed must match their needs.

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ii. Character design

Based on the sketch designed on the previous page, the character was designed by utilizing Adobe Illustration.

iii. Interface design

The interface was designed based on the storyboard prepared in the= preproduction phase by using Expo the developer tool.

iv. Insert actual content

All the actual content for “concept” and “activities” were combined and integrated with the actual coding, especially for the “activities” part, which allows users to actively interact with the AMM4LV.

v. Organize navigation

All the navigation buttons that have been specified in the pre-production phase were made active.

vi. Insert audio

Then, it is time to insert the audio recorded in the previous step to match the displayed content.

vii. Insert sound effect

It is followed by inserting sound effect that has been identified during the script preparation. Some examples of sound included in the AMM4LV are the chime for the right answer and the buzzer for the wrong answer.

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viii. Editing

A concept video for explaining the content has been inserted separately from the activities part. All the separated scenes were combined and executed as one mobile application. After having number of discussions, some parts were edited including the size of the button, text, speed of audio, and the arrangement of the elements in the application.

ix. Quality checking

Similar to the previous phase, the quality checking involves a minor step of testing the navigation throughout the application to match the flow of the navigation in the previous phase.

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5.2.3 Post-production Phase

The final stage of developing the AMM4LV is the post-production phase, which involves only three steps as illustrated in Figure 5.4, They are discussed in the following paragraphs.

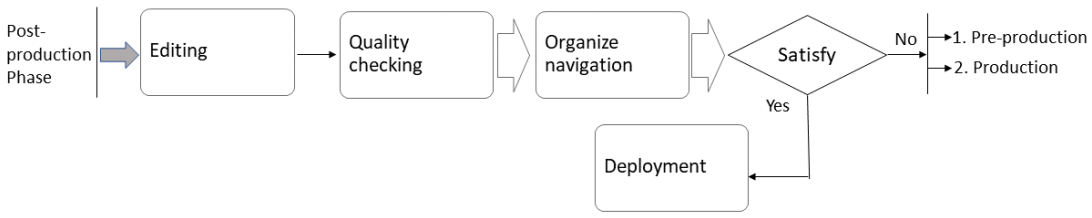

Figure 5.4 Post-production Phase

i. Editing

Based on the errors listed in the previous phase, the application was again edited. The final editing process was conducted by the researcher which also the developer of this project.

ii. Quality checking

When the AMM4LV is completed, the previewing session is necessary to check the quality. To achieve the required quality, the AMM4LV was inspected from different points of view which involved the non-technical, the actual users (low vision learners) including teachers and academicians in higher institutions.

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iii. Deployment

In this phase, the AMM4LV has been prepared to run and operate on the tablet. The AMM4LV is ready to be explored by installing the developer tool (Expo) in the Google Play store. The user can make a one-time installation to use the mobile application by using an internet connection. The tablet is the main platform to run the AMM4LV.

5.3 Application of Affective Four Dimensional Design Principles

After going through the three-phase development process, a prototype of the AMM4LV in a handy-mobile device of a tablet was produced as depicted in Figure 5.5.

Figure 5.5 The Prototype

The prototype scene maps followed affective four dimensional design principles. The AMM4LV was created with the help of teachers using the textbook they used in class. According to their experience, mathematics subject is the most critical subject for LV learners. In addition, to accomplish the goals of this study, multiple topics were merged into a single prototype. The topic is presented to the students of all primary schools from standard two up to standard six using the textbook that is supplied by the MOE. Nonetheless, the levels of difficulty in each lesson are not uniform. On the other hand, this AMM4LV is geared at the concept of multiplication, as it addresses the fundamental process of understanding multiplication.

The AMM4LV is in the Malay language to suit the targeted learners. The actual content is comprised of an explanation of the concept of multiplying as well as activities that evaluate the participants' comprehension of the concept based on a video

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that explains the concept. Table 5.1 describes the description of the prototype. It is followed by Table 5.2 which describes the actual content and the forms of activities of the AMM4LV.

Table 5.1

Descriptions of the Prototype

Main topic	Multiply
Target learners	Low vision learners
Type of actor	A primary school girl
Type of content	Formal lesson
Concept	Learning through audio and visual

Table 5.2

Descriptions of the Actual Content and the Forms of Activities of the AMM4LV

Scene	Activity	Form	Description
Concept	Explanation video of the multiplication basic concept	Watching	A video of an explanation of the concept of multiplying will be played. The users can skip this part as if they already understand the concept of the second usage of the application. This part is important to determine the understanding of the basic concept of multiplication to make them able to answer the activities section.
Activities	Activity 1 and Activity 2: Insert the number into the mathematical sentence.	Input numbers	In this type of activity, the users are required to count on the screen the illustration depicted the input of the numbers into the mathematics sentence. The sequence to input the numbers should be according to the rules in mathematics sentences for multiplying. The check button is to check the answer. On every page of the activity, it is provided with the undo button if they tend to make mistakes.
	Activity 3 and Activity 4:	Tapping	In this activity, the users will be provided with an incomplete mathematics sentence of

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	Tap the answer on the screen to choose the correct answer.		multiplication then they have to count on the screen of the illustrations depicted to complete the mathematics sentence.
	Activity 5 and Activity 6: Drag and drop into the box to illustrate the mathematics sentence.	Drag and drop	The users need to drag and drop the illustrations according to the complete mathematics sentence.

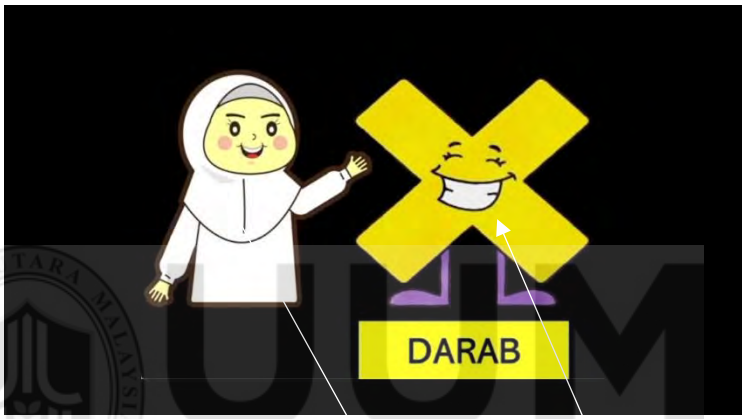
It is important to emphasize that each scene have its learning outcomes. After learning the course, the learners should be able to:

- Understand the mathematics sentence for multiply.
- Differentiate the 'groups', 'object in the group', and the 'total object in the group'.
- Distinguish the illustrations to answer the questions.
- To recall the whole lesson in learning the basic concept then to solve the exercises.

5.3.1 The Welcoming Segment

Happiness - In this segment, a welcoming audio voice from a girl named Alisya is played as depicted in Figure 5.6. Including human character as attraction is to increase the sense of happiness interacting with the contents. This is corresponding to the Multimedia Learning Theory for Children (2001). She introduces herself as the peer for today's lesson and introduces the subject of multiplying. An icon of 'multiply' has also been displayed to alert the LV learners to acknowledge what are going to learn. This icon has also been infused with a human-like character to

convey the peer- tutoring concept in learning. At the bottom of the application is the button to enter the next scene. Both button and icon are set to be clickable to direct to the next scene. This is because of larger the clickable area in case the LV learners are unable to click on the exact button. This segment is concise but attractive to LV learners. This section has minimized the use of text to avoid overloaded information for the starting lesson.



1. Imitates children voice intonation:

Entrance sound is played, addressing the name of peer and subject using a girl voice.

2. Use human character as attraction:

Alisya character is created similar to a primary school student.

Use human-like character to attract

Figure 5.6 Welcome Scene

Motivational – Creating a good colour contrast between background and foreground creates perceivable content to be delivered to the LV learners. Based on figure 5.7, the use of happy colours can enhance the motivational level of primary schools to learn mathematics. To motivate the LV learners, the colour choice must follow their most preferrable colour selection. Hence, yellow as the foreground on the black background

is suggested by experts according to a study by Nurulnadwan (2015). The content becomes more understandable when it is being interacted with by the LV learners.

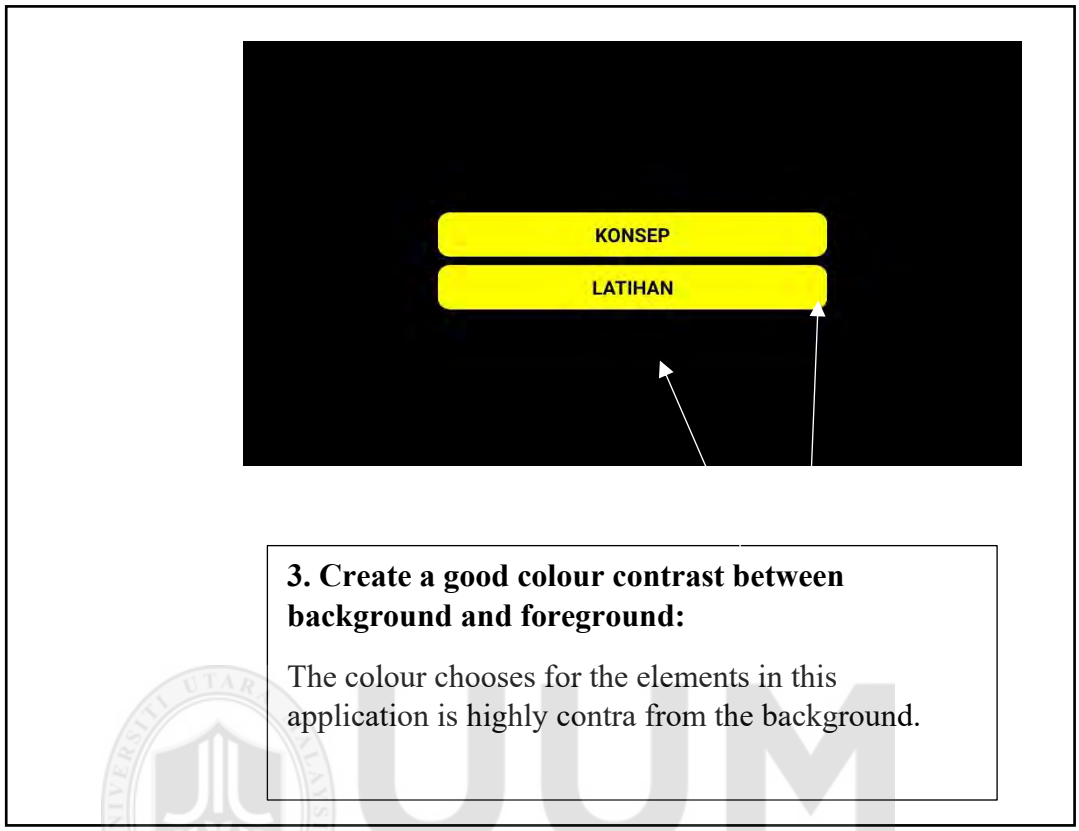


Figure 5.7 The Menu Scene

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5.3.2 The Assistive Content Segment

The assistive content segment consists of two divisions which are 'Concept' and 'Activities'. Each division has repercussions. In AMM4LV, both are created using all the affective four dimensional design principles (Chapter 4).

a) The Concept of Multiplying Scene

This scene consists of a video of the basic concept of multiplication. The video has been included with the audio and illustration. The layout and the arrangement of elements in the video have been applying the proposed affective four dimensional

design principles to ensure all the needs of LV learners could be achieved. This scene is very important as it determines the understanding of the LV learners when answering the questions in the activity's scenes.

Interest – Providing a clear and symmetrical layout requires LV learners to lessen the attention to analyse the design layout throughout their interaction with the application. This also generate the interest of LV learners who viewed the design in a proper and balance layout. Based on Figure 5.8 the layout is divided into a proportional space on every page. The arrangement of components tends to be placed proportional so that it is arranged fit and balanced in one page. In addition, based on Figure 5.9, the use of landscape orientation is the most preferrable orientation for LV learners as it gives a larger view and more space. According to the WCAG 2.0 (2018), LV learners are more interest in using the landscape orientation. People are interested in things that they enjoy and highly value while if they are not interested, they tend to avoid things they dislike (Mehrabian, 1972). Providing a favourable type of orientation can drive their interest in the application.

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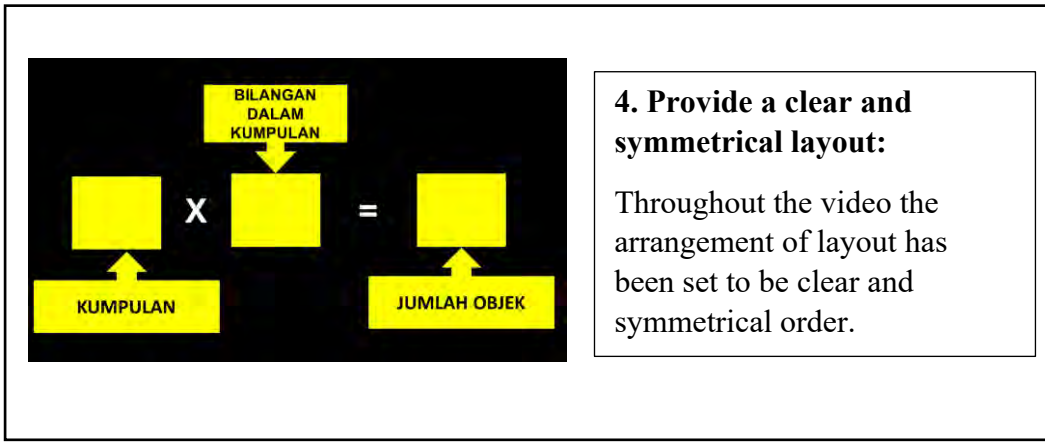
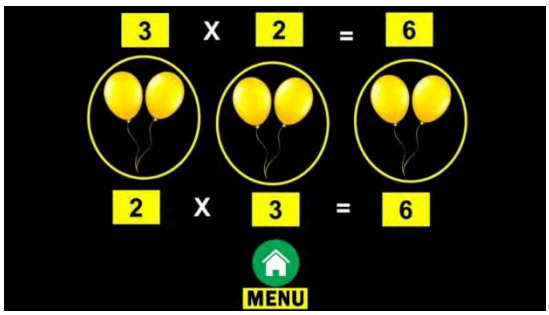


Figure 5.8 The Use of Clear and Symmetrical Layout



5. Use of landscape orientation:

The whole screens are implementing the landscape orientation for a bigger view for LV learners.

Figure 5.9 The Use of Landscape Orientation

Positive Mind States – The state of mind is triggered by some circumstances whether internal or external stimuli. This application focuses on the external stimuli or visualization that has been served in this mobile application. Based on Figure 5.10, the best size of text used is 18 points and above. In addition, based on Figure 5.11, all the components chosen in the interface are highly contra form each other. The difference in colour selection between each of the interface components (non- text components) acts as a good external stimulus that led to a positive state of mind. LV learners may have perceptible content delivered to them which will create an instant perception of appearance and pleasure to see a well-designed product (Aftab & Rusli, 2017).

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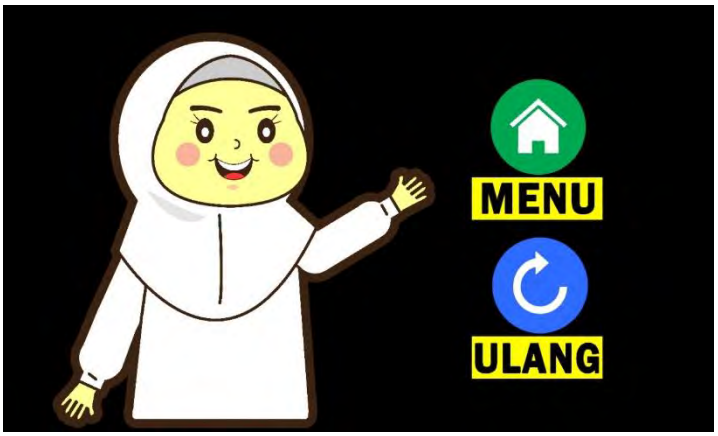

6. Use the biggest text font:

The size of text use is deployed to use the biggest text size to be readable enough to the low vision learners.

Figure 5.10 The Use of Biggest Text Font

7. Use highly contrast of interface components:

Each of the button are coloured differently and been arranged accordingly next to each other that has completely different colour. For example, the tap button for the answer which for the low vison to differentiate the answers is in different boxes.

Figure 5.11 The Use of Highly Contrast Interface Components

b) The Activity Scene

Content delivery formatted in this scene is all based on the proposed design principles to ensure that LV learners are able the answer the question with the correct answer. This scene also verified the previous scene (understanding of illustration along with the audio explanation) if they are able to answer the correct answer in the following activities:

- Look and count the illustrations then input the numbers,
- Look and count the illustration then tap the numbers for an answer,
- Count then Drag and drop the illustration into the answering area.

Memorable – Providing consistency in design by locating the interactive components at the same position on all screens. Based on figure 5.12 depicts the consistency in interface of prototype throught button layout and arrangement. This suppresses the visual consistency in a mobile application where the LV learners will easily remember and indicate the same information as previously viewed on another screen. This provides a memorable experience to the LV learners, and they do not relearn the unnecessary steps to operate the application by themselves.

8. Provide consistency in design:

The type of button for every page is in the same place to avoid the learners relearn the function of every same button

Figure 5.12 The Use of Consistency in Design

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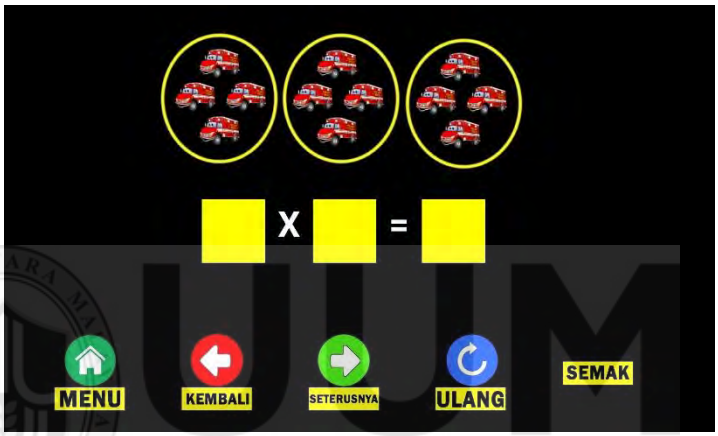
Positive Perception - Provide button labelling using words and sound to synchronize the user on what they see and what they hear when clicking the button. According to Norman (2005), a design that works at a visceral level (perceptually based) is affected by appearance. It is a good indicator for signalling principles implemented in the name labelling for each button. Hence, this design principle enables LV learners to acknowledge the functional button and address the user navigation correctly by name labelling on the button.

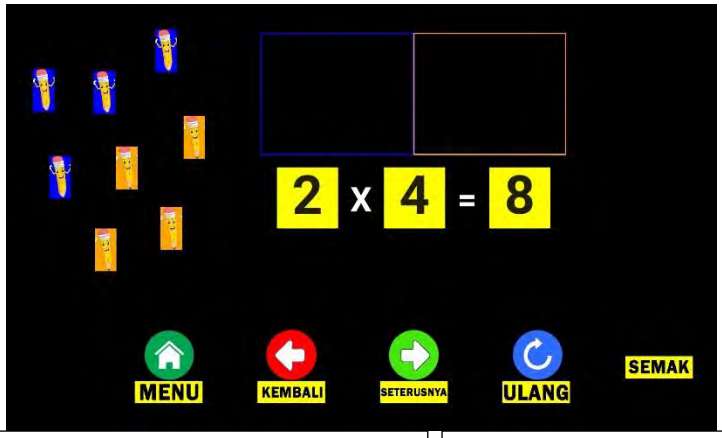


9. Provide name labelling for each button:

The buttons are labelled according to the sound produce when they click the button.

Figure 5.13 The Use of Name Labelling for Button

Navigation – Ease of navigation may result in feelings of satisfaction when interacting with the application (Coetzer, 2017). The navigation option should be on easy to find a place on the page as for LV learners, it is ease for them to allocate the button as it is placed at the edge of the application.



10. Use non-linear navigation: This will ease the users to navigate the application to any page.	**11. Place button at the edge of the application:** This will make the button is more reachable for the LV learners.

Figure 5.14 Use Non-Linear Navigation and Button Placement at the Edge

Interaction – Providing feedback and acknowledging LV learners about their answers whether right or wrong. After receiving feedback, they can choose the next action to interact with the mobile application. This will confirm the LV learners on what to practice and what to avoid. The interaction in this activity scene involves three sequences, which are initiation, response, and feedback (Evans & Gibbon, 2007). First, the LV learners are able to control all the buttons or control features to push or interact for the next action, Second, the LV learners press the button or control features for the next action. Lastly, the next page appears on the same page because of the action of LV learners pushing the button in the last action sequence. In this context, when the LV learners completed answering the questions, they will push the "Semak" button to check the answer, then the feedback of "Betul" or "Salah" will appear. Meanwhile, this activity scene also provides an error-handling button such as "Ulang" to clear or cancel their answer, LV learners will tend to do mistakes or want to try to repeat the question. The "Ulang" button acts as an error-handling button that allows LV learners

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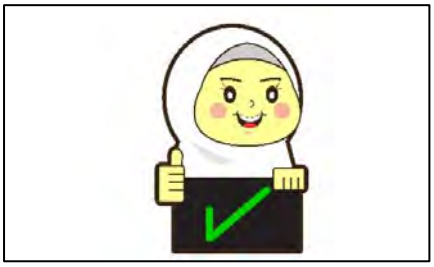
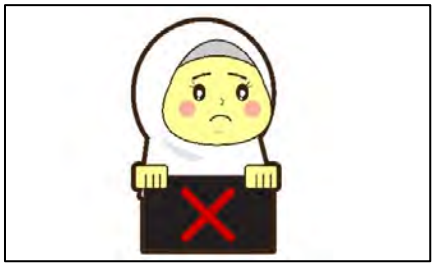
to undo their mistakes in answering the questions. This interaction can improve LV learners' learnability and understandability.





12. Feedback:

This will make LV learners to acknowledge the previous events. For the "Correct" feedback, the page pop-up with the chime sound noting the LV learners that their answer is correct. Meanwhile, for "Wrong" feedback along with the buzzer sound noting that the answer is wrong.

Figure 5.15 Feedback

13. Provide error-handling:

The user will be able to undo and redo if they are performing mistake using button "Ulang". In the activity scenes LV learners will be provided with menu button, back and forward button, repeat or clear button and check button. All the buttons act as error-handling button that allows user to control the application with non-linear navigation using the control buttons.

Figure 5.16 The Use of Error-handling Button

5.4 Prototype Validation

Table 5.3 shows the additional suggestions and feedback given by the experts. Recommendations made by Expert A are likely more to interface of the mobile application. Then, Expert B mentioned the degrees of low vision for each of the subjects chosen. The medical report on each LV learners should be obtained to ensure maximal acceptance of the design principles proposed according to their level of low vision. Then, Expert C also suggests verifying the application by the low vison teacher to validate the design principles used. Expert D suggests taking proper consideration of the chosen colour. While Expert E suggests reducing the navigation path such reduce the clickable buttons on the screen.

Table 5.3

Additional Feedback and Comments of Expert Review

Expert	Feedbacks and Comments	Justifications
A	• The multimedia elements must be compatible with the size of the device used	• The size of the application may be varied according to the tablet model. However, the best view for this application is by using 10 inches model of tablet.
B	• Need to obtain the medical report on the users to make sure they are suitable for using the application	• This study has selected all the participants that have 'blurry' low vision and eliminated all the respondents that have 'totally' blind.
C	• Test the application to the actual user of low vision to obtain the exact experience of interacting with the application.	• This test will be done upon pilot testing to obtain the exact experience of the interaction towards the application.

D	• Increase the colour contrast on the multimedia elements in the application.	• Instead of increasing the colour contrast this study also admits enlarging the size of the elements in the application. So, this increases the contrast between foreground and background.
E	• Minimize the buttons on the screens to avoid the application to looks crowded. Or give them spaces to avoid unwanted clickable action.	• This study provides an 'error-handling' button which requires different buttons to give access to the user to attend/ leave their action.

Based on Table 5.3 the academician's expert touches more on the interface design and the user's condition in receiving the application with the proposed design principles while agreeing to all the affective four dimensional design principles that could lead the to the positive emotion of the low vision learners while engaging with the mobile application.

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This study examines a design application with affective and assistive elements to convey learning information to LV learners. AMM4LV affective and assistive elements keep LV students engaged and focused.

5.5 Summary

This chapter discusses the method of prototyping that is used to validate the affective four dimensional design principles . AMM4LV was built with the primary purpose of validating the affective four dimensional design principles proposed in this study. It was developed according to the guidelines suggested criteria for affective design,

which involved the three primary phases of pre-production, production, and post-production respectively.

Also, the elements and affective four dimensional design principles that are derived from the affective Four Dimensional components depicted in the snapshots are translated in this chapter. Eventually, the prototype is ready for use to gather data in the planned user testing. Next, Chapter 6 discusses on user experience testing.

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CHAPTER SIX

USER EXPERIENCE TESTING ON AMM4LV

6.1 Overview

Chapters 1 and Chapter 2 explore LV learners' learning obstacles and assistive mobile applications for visually impaired people on accessibility issues. Chapter 4 proposed affective four dimensional design principles for mobile applications designed for LV learners to solve the challenge. Expert review validated the design concepts. In Chapter 5, validate the design principles through prototypes to achieve the second goal. This chapter discusses the four dimensional user experience , covering emotions, feelings, thoughts, and actions.

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6.2 Pilot Test with Low vision Learners

Qualitative testing differs from quantitative testing. The pilot test was to explore the user experience testing's wellbeing and homogeneity. The AMM4LV prototype is tested for practicality, equipment, and data collection issues (Herrington, 1997). This investigation determines if the AMM4LV prototype, equipment, or data gathering methods have any defects, restrictions, or other problems, allowing this study to make necessary adjustments before starting the main user experience testing study, as indicated by Turner (2010) and Kim (2010). (2011). This study executes one pilot test cycle to achieve the second objective, as described in section 6.2.1.

6.2.1 Pilot Test

The pilot test was conducted in a Malaysian visually impaired primary school. Table 6.1 shows four LV children ages seven to nine who participated in this exam. Three females and 1 male. One girl is unwell and absent. Three people were tested. This homogeneous sample size is sufficient for a qualitative research pilot project to appropriately represent the local or worldwide LV learner group.

Table 6.1

Demographic Background of the Subjects Involved in the Pilot Test

Subjects	Age	Gender	Race	Level of School
Subject 1	7	Female	Malay	3 years
Subject 2	10	Female	Malay	4 years
Subject 3	7	Male	Malay	1 year

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6.2.2 Procedure

Participants were expected to feel more comfortable in their regular classes. The test was administered in a classroom. One-to-one testing was carried out. The flow was the introduction, observation, focus group interview, and conclusion.

The AMM4LV application was installed on a tablet before the testing began. Recording sheets and a video recorder are also provided to record the interview and observation session. Appendix F attached the permission letter to the parents to record their child on video.

Having setup, up the equipment the subjects were asked to sit in a classroom to listen to the overview of the subject that will be tested. The teacher explained the basic concept of multiplication to the children as one of the subjects involved is standard one where the syllabus is not in her standard yet. However, the teachers told that even without the explanation all their students can do it as they are quick learners during their study. But to ensure the smooth process of the pilot test we recommend giving a slight explanation of the subjects before they engage with the prototype. They were also have been briefed by introducing the team researcher and the purpose of this study.

After finishing the first session, they were taken into the next room. At first, the test was expected to be carried out simultaneously, however, there is a technical issue so then we tested one by one of the three subjects. They explored and understood AMM4LV sub-topics and exercises in 10–13 minutes. The researcher and team members used that allocation to take photos, videos, and notes. The testing session included the focus group interview. This session involved semi-structured interview questions. The sessions were closed by thanking and giving a token to the subjects.

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6.2.3 Findings of the Pilot Testing

The pilot test must address various concerns and inadequacies before user experience testing. When revising the main study, the prototype's viability and data collection methods were considered.

(i) Problems with the AMM4LV (feasibility study of the prototype)

After quality control, the AMM4LV was finished five days before the pilot testing and was not expected to have any issues. However, the prototype used in the pilot test unearthed a minor "bug" that needs fixing. The issues include (i) display resolutions vary widely across different sizes of tablets. The size of the content fits according to the screen. Since there are various sizes of tablets that we have 8-inch and 10-inch sizes, the 10-inch size of the tablet is the most preferrable size for LV learners. Somehow, we only have two tablets of 10-inch size. Second problem (ii) navigation redundancy for certain activities especially at the tap style of answering the questions. The feedback should immediately pop-up once the user taps the answer. However, the researcher is tied with the consistency in the button despite of practicality of that question which should immediately pop-up the feedback after tapping without the need to press the check button. Nevertheless, all the problems were brought to the attention of the developer to correct for the main testing.

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(ii) Problems with the Data Collection Methods

The pilot test also found equipment settings-related data gathering difficulties. These factors hinder user experience testing. Table 6.2 lists data-gathering issues, causes, and solutions.

Table 6.2

Problems, Causes, and Solutions Detected in the Pilot Test

Problems	Causes	Solutions
Audio disturbs each the group	The audio produced by the tablet is distracting the next user	Use headphones to exclude the audio from the surrounding.
The audio quality produced is different for each model of the tablet	The audio produce from low-quality or small tablets, an 8-inch tablet is not louder than a 10-inch tablet	Use headphones to produce clear audio.
Screen size differ as different size of the tablet	The application fit to the screen. When the screen is bigger the view also becomes bigger.	Standardize the use of 10-inch tablets only for the main testing.

It is essential to provide one tablet to one subject which provides them the opportunity to practice using AMM4LV on their own. This is because of the findings collected from the experiment, which showed that the audio cannot be played directly with the tablet speaker since it caused the other participant to become distracted. Since that, each participant conducted their tests during the real process. Even this technique did not affect the overall results; however, the subjects all agreed that the experience of utilizing AMM4LV was crucial.

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6.2.4 Implications of the Pilot Test to the Study

This study performs the real study of user experience testing based on the pilot test and the rich experience that was obtained as guidance for this study use. It has been pointed out by Kim (2010) that the production of results is not necessarily the purpose of a pilot study. Consequently, the feasibility study has been carried out through a pilot study. Therefore, the problems that arise during the pilot test have been encountered and the solutions have been addressed. It was discovered that each person needs to go

through their own AMM4LV experience. Because testing the AMM4LV in groups was judged to be impractical for this study, this finding indicates that one tablet is assigned to each subject. In addition, the semi-structured interview must be carried out one-to-one rather than in the form of focus group interviews for the reasons that were discussed previously.

6.3 User Experience Testing

As mentioned earlier in this chapter, user experience on AMM4LV examined LV learners' emotional four dimensional design principles in terms of emotion, feeling, thought, and action. Next, the demographics of the subjects and findings are explained.

6.3.1 The Demographic Background of the Subjects

Testing of user experience was conducted at the Primary School of Jalan Hamilton (Appendix G attach the application letter obtained from the Special Needs Department). Table 6.3 shows that four male and three female students were tested. Most students have used tablets from standard one.

Table 6.3

Demographic Background of the Subjects Involved in User Experience Testing

Subjects	Age	Gender	Race	School Level
Subject 1	9	Female	Malay	3 years
Subject 2	10	Male	Chinese	4 years
Subject 3	9	Male	Chinese	3 years
Subject 4	12	Male	Malay	6 years
Subject 5	10	Female	Malay	4 years
Subject 6	12	Male	Malay	6 years
Subject 7	8	Female	Chinese	2 years

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6.3.2 Analysis of Findings on User Experience Testing

The findings on user experience were analysed based on four components of affective 4-Dimentional design principles: (i) emotion, (ii) feelings, (iii) thought, and (iv) action. The analyses were also divided into observation and interview.

(i) Observation

Observation has been conducted based on the four key components of affective four dimensional design principles, and each of these is explored in detail in the article. Two different aspects of the observation were recorded: the scene and the states. Within the mobile application, there are a list of scenarios or activities that the participants are most likely to take out. The subjects' reactions to the interaction, as well as the factors that caused those reactions, are referred to as the subjects' states. However, the main focus of this observation is to focus on the clarification of the affective four dimensional design principles not the subjects' emotional states. Figure 6.1 shows the scene coding scheme. The minutes correspond to how long the subjects stay at the scene (welcome scene, menu scene, concept of multiply scene, and activities scene) with their current state engaged with the scene.

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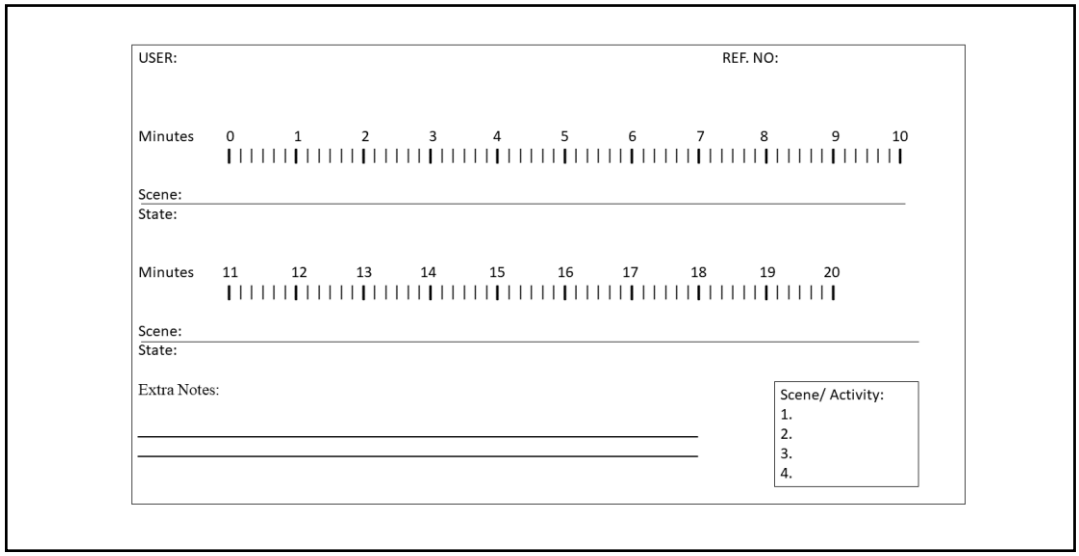

Figure 6.1 Scene Coding Scheme

a. Four Dimensional Component: Emotion

User experience investigates emotion through the items derived from the emotional components which are memorable and motivational designs.

- **Memorable**

On the extend of LV learners by providing consistency in design by using similar graphical elements such as buttons, and icons for LV to memorize the gesture throughout the navigation process of the mobile application. LV learners need not relearn the gesture every time they use the mobile application. In the application, the navigation button is mostly placed in the activities scene such as the next button, back button, replay button, redo button, and check button. Based on the Scene Coding Scheme, the timing recorded for the first question are longer than the others question. The longest time recorded for Subject 1 and Subject 6 is three minutes. In addition, Subject 6 positioned themself while interacting with the application by tilting his head. Subject 6 also had a problem in differentiating the colour of boxes in the drag-and-drop

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activities. While the rest take about two minutes to understand and answer the questions. The first question in the activity's scene was about the first time the LV learners were introduced to the functional buttons. This is because, in the next five questions, the timing recorded was a minimum of less than one minute and shorter by the time they proceed to the next questions. According to the Scene Coding Scheme, the longest time recorded for the subject to interact with the application is 15.5 minutes which timing recorded by Subject 4. Subject 4 has bad eyesight among others and not wearing any visual aid such as spectacles. Subject 4 was still asking "Where is the button?" even moved on to the next question. However, most of the subjects were found clicking all the functional buttons correctly after the second activity, especially in the activities scene after showing them for the first time. Based on the time recorded on the Scene Coding Scheme, the average timing for them to complete using the application is in seven to nine minutes. Five from seven subjects who interact for less than ten minutes with the application tend to memorize well and spend lesser time between questions as they memorize the functional buttons as use the same interface as the button. An example of a scenario can be seen in Figure 6.2.

- **Motivational**

All the subjects operate the application until the end. Based on Table 6.4 findings indicate that the subjects are motivated in accessing the information in AMM4LV. Furthermore, this study offered each of the subjects to repeat and play alone and all the subjects agree to repeat and were excited to play more activities scene. This shows that they can distinguish what they were

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interacted such as the colour contrast on the whole scene which prolongs the use of the application until the end. However, during the concept video scene, Subject 4 (bad eyesight) seems distracted by adjusting the headphone while waiting for the video to finish. However, during the activity scene, Subject 4 is very motivated to finish all the questions.

Table 6.4

Observation Findings. Summary of four dimensional Components: Emotion

Affective four dimensional design principles	Elements	Scene	State
Provide consistency	Memorable	Activities scene	- Subject 4 asks "Where is the button?". - Subject 6 tilting his head to look at the screen makes the navigation process a bit difficult for him. - Subject 5 continue to click the navigation button on her own after one-time assist on question 1.
Create good colour contrast	Motivation	All scenes	- All the subjects were motivated to finish playing till the end and were eager to repeat the session. - Subject 4 with bad eyesight takes a longer time to finish the questions.

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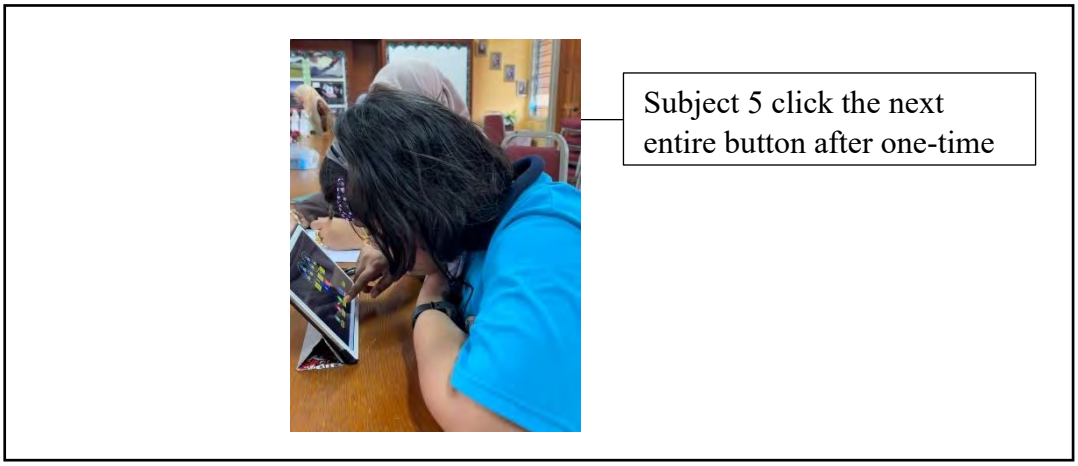

Figure 6.2 Clicking Next Functional Button Without Assist

b. Four Dimensional Component: Feeling

User experience investigates emotion through the items derived from the emotional components which are interest and happiness.

- **Interest**

Provide a clear and symmetrical layout to inculcate a pleasant experience that can generate interest in LV learners. A balanced design requires less attention from LV learners to analyse the design due to their eye limitations. All the subjects were found able to locate and reach the button easily due to the arrangement of the layout. In fact, Subject 5 pressed the button before the command finish after getting familiar with the AMM4LV. The "Next" button was positioned to the right, and the "Back" button was positioned to the left. Symmetry in design creates a sense of harmony while making it easier to take in the whole picture. The symmetrical arrangement also requires less attention to analyse the design. However, as the check button is located on the right side and next to the redo button, Subject 4, Subject 6 and Subject 7 mistakenly clicked the button as it placed next to each other. Meanwhile, sitting also shows them there are comfortable using the landscape orientation, while the view tends to be larger than in

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portrait orientation. In addition, 5 out 7 subjects agree on using the landscape orientation. While Subject 3 and Subject 5 prefer portrait orientation. This shows by the sitting of the subject depicts in Figure 6.3. Subject 6 held the tablet comfortably while clicking to answer the questions in the activity scene.

- **Happiness**

Furthermore, using a schoolgirl character can build an engagement of happiness with the LV learners. All the commands used girl's voice and the voice used are clear and the LV learners receive the commands. All the subjects follow the instruction at the activity scene correctly. As for the girl character, named Alisha, Subject 1 and Subject 4 speaking-loud the explanation from the video concept of multiply. Meanwhile, Subject 3 asked to repeat the concept video of Alisha. This state shows they are happy with the character as their peer-teaching. Figure 6.3 depicts the LV learner is holding the tablet comfortable in front of the tablet while Figure 6.4 depicts the subject is pointing to the tablet while speaking-loud following the explanation from Alisha. Table 6.5 shows the observation findings based on the component feeling.

Table 6.5

Observation Findings. Summary of four dimensional Components: Feeling

Affective four dimensional design principles	Elements	Scene	State
Provide a clear and symmetrical layout	Interest	All scenes	- Subject 5 pressed the button before the command finish after getting familiar with the AMM4LV.

			- Subject 4, Subject 6, and Subject 7 mistakenly clicked the button as they placed next to each other
Use landscape orientation	Interest	All scenes	- Subjects 3 and Subject 5 prefer to have portrait orientation out of 7 subjects.
Imitates children voice	Happiness	Activities scene	- Subject 3 asked to repeat the concept video scene to hear the explanation from Alisha.
Use character	Happiness	Concept of multiply scene	- Subject 1 and Subject 4 repeat the words from Alisha in the concept video scene.

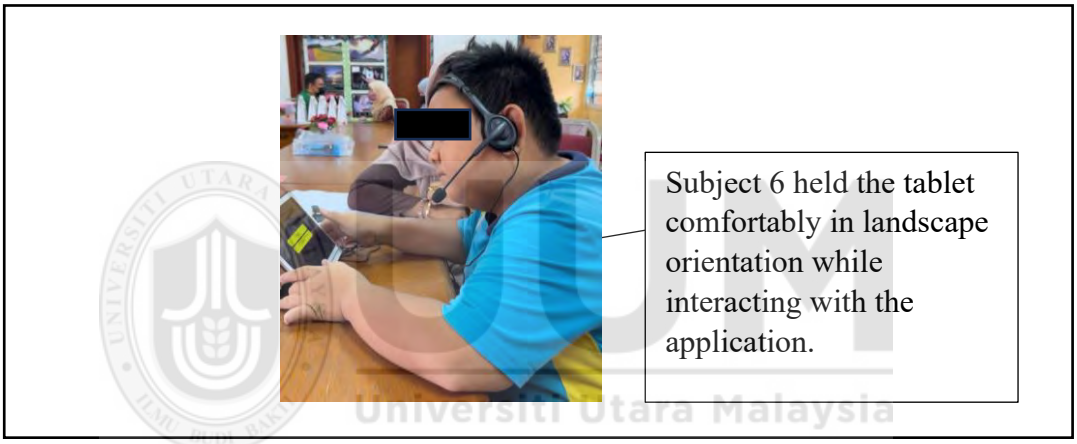

Figure 6.3 Subject's Sitting While Using the Application

Figure 6.4 Subject's State While Using the Application

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c. Four Dimensional Component: Thought

User experience investigates the emotion through the items derived from the emotional components which are positive perception and positive mind state.

- **Positive Perception**

When the audible labels match the visual text labels on the screen, the user experience improves for those with low vision. This gives a positive perception of delivering the visual content to the LV learners at the first sight. Subject 2 was confused about which home, then tend to read the name label and understand the button and proceed to the next scene. All the subjects tend to mumble reading the button label if they lost navigation. This will make the LV learners have a positive perception of operating the application alone However, mostly this happens on the first question as all the buttons are mostly placed in the scene. The button is also equipped with sound. Hence, they have a better experience in assisting them in using the application.

- **Positive Mind State**

However, for the font size, the conditions of states received were different for those with spectacles and without spectacles. Those with spectacles have a proper distance from the tablet. Meanwhile, those without spectacles intend to come near the tablet. There are 3 over 7 subjects wore spectacles. However, Subject 4 have the worst eyesight level was not wear spectacles tend to sit the nearest to the tablet. Figure 6.5 depicts the distance between the subject with the tablet. Meanwhile, all the subjects were able to distinguish the non-text components such as buttons, icons, and images

as they are able to answer the questions that requires them to count on screen. Most of the subjects were able to count and input the answers on the screen.

Table 6.6

Observation Findings. Summary of four dimensional Components: Thought

Affective four dimensional design principles	Elements	Scene	State
Provide button name labelling	Positive perception	All scenes	- All subjects refer to the button label if they do not know where to click. - Subject 2 confuse about the home button then tend to read the label.
Use the biggest text font	Positive mind state	All scenes	- Subject 5 without spectacles complaints about the font size while subjects with spectacles accept the font size.
Use highly contrasted interface components	Positive mind state	Activities scenes	- Subject 2 and Subject 5 rarely cannot distinguish the components

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Distance between Subject 2 versus Subject 7 with the tablet.

Figure 6.5 Distance Subject from Tablet

d. Four Dimensional Component: Action

User experience testing investigates emotion through the items derived from the emotional components which are navigation and interaction.

- **Navigation**

Navigation implemented in this application is dynamic, the subjects may across any scene they want. Hence, the button is placed at the edge of the table screen, so that all the buttons are not mixed with the content. All the subjects acknowledge the button placement which is at the bottom of the screen.

- **Interaction**

In addition, to create an interaction for the subject the feedback for their answer has been included in every question they answered. This indicates a clearer action needed and to be accomplished by the subjects. This also acts as an appraisal of the subjects after answering the questions. They feel rewarded with their correct answer by chiming the sound produced on the correct answer while a buzzing sound is produced when the answer is wrong. Figure 6.6 and 6.7 depicts the states of Subject 6 and Subject 3. Subject 3 smiled after getting the right answer while Subject 6 raised their hand after getting feedback on the right answer. Due to the visual condition of Subject 6 which needs to tilt his head for better sight, he tends to make a few mistakes in the drag and drop activities scene. However, Subject 6 redo the questions using the button that reset

the questions. By providing error handling to the user, they do not need to close the application to restart the same question.

Table 6.7

Observation Findings. Summary of four dimensional Components: Action

Affective four dimensional design principles	Elements	Scene	State
Place the button at the edge	Navigation	Activities scene	- All subjects are aware of the button placement.
Provide feedback	Interaction	Activities scene	- Subject 6 raised their hands after getting the feedback right answer. - Subject 3 smiled after getting the right answer. - Subject 6 again express dissatisfaction with drag and drop
Provide error handling	Interaction	Activities scene	- Subject 6 repeatedly uses the redo button to clear to redo the question.

Figure 6.6 Subject 3 Smiling

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Figure 6.7 Subject 6 Raising a Hand

(ii) Interview

Interviews supported observation data. Table 6.7 lists interview questions. The inquiries about the mobile application and four dimensional components are based on their opinions and experiences. This study aims to clarify the affective four dimensional design principles of the mobile application. The interview questions were analysed based on the elements in four dimensional components through affective four dimensional design principles applied in AMM4LV. They are discussed separately.

1. Four Dimensional component: Emotion

    - Consistency

    Questions related to affective four dimensional design principles of memorable and motivational. (Q1: memorable) “does it makes you easy to remember?”. Their answer was similar to “easy”. Subject 5 added, “it was easy to remember”. This proves that they have no problem operating the mobile application as during the user experience testing all the subjects manage to complete including repeat to play the same scene in the mobile application. In addition, the second time playing the application they tend to memorize the button in the application.

- Good colour contrast

Next, move to the next question (Q2: motivational) “is the colour ok for you?”. Subject 4 (bad eyesight) and Subject 5 informs that “little ok”, and “a bit hard” they answered respectively. This means the colour contrast needs to be corrected. This is because providing appropriate colour contrast is important for the LV learners to make them feel motivated and prolong their time to use the mobile application for their learning this is because LV learners are easily distracted. However, this user experience testing was conducted on LV children with various levels of vision impairments. Hence, the interview shows that it only happens to subjects with bad eyesight and during the user experience testing, they sit too near to the screen. Their sitting position and behaviour could tell the observer they were having difficulties with the colour contrast.

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2. Four Dimensional Component: Feeling

    - Clear and symmetrical layout

    In conjunction, the question related to the layout of the AMM4LV was asked of the subjects. (Q3: interest) “What is feeling the first time seeing this mobile application?”. Most of the answers said, “excited”. Subject 2 added, “I am proud to use this”. Meanwhile, Subject 1 said, “it is easy to use”. This proves that the subjects have no problem with the interface layout throughout each scene. The button is arranged symmetrically to ignite the interest of LV learners in the overall experience with the application.

- Landscape orientation

Then, a further question was asked (Q4: interest) “do you like the orientation?”. All subjects agreed on the landscape orientation. 5 over 7 subjects prefer landscape orientation and three of them mentioned about the size of landscape orientation is much bigger and they like it. While the other two subjects (Subject 3 and Subject 5) prefer landscape orientation. However, the majority of the subjects prefer landscape orientation and added size as the main reason they choose that orientation.

- Imitates children's voice intonation

In investigating their feeling about using AMM4LV, a question regarding their happiness were asked (Q5: happiness) “do you understand the video?”. All the subjects answered “understand” while the other two subjects (Subject 5 and Subject 7) added, “understand, like the teacher”. This shows that they are accepting the voice used in the video and understand the lesson explained and the instructions in the AMM4LV. The video consisted of an explanation of the multiply concept which use the voice tone of a girl to explain the multiply concept. The whole application is using the same voice of a girl through instruction and explanation in every scene of the mobile application.

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- Human character

Then, responding to (Q6: happiness) “do you like the character, Alisha?” all of the answered they liked the character, Alisha. The character used in the mobile application is a cute schoolgirl throughout the welcome scene, concept scene, and feedback scene. Subject 2 answered, “understand and happy with Alisha's explanation”. Subject 3 also added “I love to see the picture” which Subject 3 liked the appearance of the character. This shows their feeling of happiness to see Alisha as the character in the mobile application.

3. Four Dimensional component: Thought

- Button label

Moving on to their thought on the button function which has been labelled each of the buttons to ease them to differentiate the button function so question (Q7: positive perception) “do you think you understand the button function?”. All of them responded to the question positively. In addition, having the button labelled eases them to try another alternative if they cannot understand the button, they tend to read the label. Button label also acts as guidance for them. This shows button labelling helped to assist LV learners to understand the button function.

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- Large font

About the font size was asked in (Q8: positive mind state) “did the font large enough?”. So, 4 from 7 subjects agreed that the font is suitable. The respond from Subject 2 is “the font can be seen”. While the other three subjects (Subject 3, Subject 4, and Subject 5) answered, “small font”, “small”, and “bit small” respectively. However, the subjects who respond to “small” size they are having a severe level of LV. So, their answer might be affected due to their poor eyesight level than the others who agreed with the font size.

- Highly contrast of interface components

Last question of the thought component (Q9: positive mind state) “do you think you can use this mobile application alone?”. All the subjects answered they can play alone without help. In addition, during user experience testing when the observer asked, “do you want to play again?” all the subjects wanted to play again. All the subjects started from the beginning concept scene (video explanation from Alisha) and answer the question from the activities scene all by themselves. They navigated the mobile application using the interface components such as buttons to move to every scene that they want without any help. This shows that the interface components in the AMM4LV are highly contrasted as they are aware of the interface components as they can operate the AMM4LV alone.

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4. Four Dimensional component: Action

- Place the button at the edge

In investigating their action of navigating the AMM4LV (Q10: navigation) they were asked “do you feel easy navigating the AMM4LV?”. All the subjects answered “easy”. Subject 1 added, “it is easy to learn”. Subject 2 and Subject 3 also added: “easy to use”. This shows the button placements are reachable and they are aware of the functional button. In addition, the medium used for the AMM4LV is a handheld tablet. Hence, the button placement is more reachable if it the place at the edge of the screen.

- Feedback on action and error handling

A further question was asked (Q10: interaction) “was it easy to interact with AMM4LV?”. All the subjects answered, “easy to use”. However, Subject 2 expressed dissatisfaction with the interaction of drag and drop in the activity scene. “The drag and drop are a bit difficult to use”. In addition, during the user experience testing Subject 2 was found to have a problem with the drag-and-drop activities. The action is quite difficult for LV learners. This shows that drag-and-drop action may be excluded from the action. Furthermore, Subject 6 added “difficult to erase” for error handling while answering the question, the redo button will reset all the answers even if he wanted only to redo one action. As the closing questions, they were asked whether they want to play again or not. All of them are really interested to play again.

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6.4 Summary

Each user tested the AMM4LV independently in user experience testing. By observing the users' behaviour, the AMM4LV meets their emotion, feeling, thought, and action. Their semi-structured interview thoughts corroborate it. This shows that they can employ all four dimensional components.

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CHAPTER SEVEN

CONCLUSION

7.1 Overview

AMMLV is developed for LV learners, hence this study proposes affective four dimensional design principles. The proposed design principles are for non-technical developers like teachers and parents who are interested in developing AMM4LV. This study addressed two research questions:

iii. How to construct the affective design principles ?

iv. How to validate the affective design principles ?

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Hence, to accomplish the main aim objectives were outlined:

iii. To construct the affective design principles through comparative analysis and a user-centered design approach.

iv. To validate the affective design principles through prototyping, expert review methods, and user experience testing.

The next sections explain the answers offered for each research issue, analyze the study's theoretical and practical consequences, and lastly discussion of future research and the study's general conclusions.

7.2 Research Question 1

How to construct the affective design principles ?

Prior to developing the affective four dimensional design principles suitable components and elements are identified. The affective four dimensional components consist of (i) emotion, (ii) feeling, (iii) thought, and (iv) action were listed. Through the operational definition of Affective four dimensional components, the elements were derived. Overall, there are eight elements identified from the operational definition which are (i) memorable, (ii) motivational, (iii) interest, (iv) happiness, (v) positive perception, (vi) positive mind state, (vii) navigation, and (viii) interaction. Hence, from the elements, the affective four dimensional design principles were designed based on the affective elements.

Meanwhile, the affective four dimensional design principles contain special elements of affective that make it different from the previously existing design principles. It is called AMM4LV affective four dimensional design principles which are divided into thirteen affective four dimensional design principles (i) consistency, (ii) good color contrast, (iii) clear and symmetrical layout, (iv) landscape orientation, (v) imitating children's voice intonation, (vi) human character, (vii) button label, (viii) large font, (ix) highly contrast of interface components, (x) Use non- linear navigation, (xi) place button at the edge, (xii) feedback of action, and (xiii) error handling.

Although the proposed affective characteristics seem familiar, the AMM4LV's affective elements make it distinctive compared to previous design principles. Literature study, comparative analysis, and UCD approach assemble all proposed components and elements.

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7.3 Research Question 2

How to validate the affective design principles ?

The affective four dimensional design principles have been evaluated through three stages namely, expert review (Chapter 4), prototyping (Chapter 5), and experimental study through user experience testing (Chapter 6). The proposed model is validated through expert review and prototyping. These three evaluations on the AMM4LV's final implementation of affective four dimensional design principles provide concrete evidence of the useful and proven benefit to its target audience of students with LV and the developer.

All the experts that were consulted for this study agreed on the affective four dimensional design principles provided for AMM4LV. Findings in the user experience testing of the AMM4LV with real-world users showed that it met the expectations of LV learners in all four dimensional affective components. It follows that the affective four dimensional design principles for AMM4LV that have been proposed will prove to be very helpful in future design and development.

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7.4 Aim and Objectives: Revisit

After completing the two supporting objectives, this study achieved its main goal. The first goal, identifying AMM4LV components and elements, was achieved (Chapter 4). The construction of the proposed affective four dimensional design principles (Chapter 5) was successful in achieving the second objective. Twelve impactful Four Dimensional design principles are included. Expert review shows that affective four dimensional design principles are valid to be prototyped.

The evaluation of the AMM4LV prototype through user experience testing with LV learners acting as the subjects were finally successful in achieving the second objective. The reaction of the respondents, which was gathered through observation and interviews, reveals that AMM4LV is helpful in terms of the affective component of design principles that are based on the Four Dimensional components of emotion, feeling, thought, and action.

7.5 The Implication of Study to Theory and Practical

This study affects current knowledge and future theoretical and practical research. User experience testing shows AMM4LV affective design concepts for LV learners are based on affective aspects. These discoveries are significant for theory and knowledge. Previous moSbile applications included many design ideas based on established guidelines, but they did not address the affective or emotional demands of LV learners. In conclusion, this research concludes that the design principles , which are based on existing guidelines and theories and supported by the UCD approach, are crucial in ensuring that all affective elements in AMM4LV cater to the affective four dimensional design principles in terms of LV learners' emotion, feeling, thought, and action towards the interaction.

So, this integration of affective aspects increases their engagement and comprehension of mathematics subject. Thus, the AMM4LV stands out from any other competing mobile applications. Hence, the affective design concepts proposed in this research greatly benefit LV students (Chapter 6). Through the AMM4LV, the information is made accessible in an affective way for the LV learners, which adds value and alters the current body of knowledge.

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At the same time, the recommended affective four dimensional design principles were constructed as a guideline and reference, especially for novice and non-technical developers, such as teachers, and parents, who are interested in creating the AMM4LV.

Meanwhile, AMM4LV is a tangible artifact that has the potential to serve a useful business purpose through its content. Those who have the resources to implement their ideas and knowledge but lack the technical expertise necessary to market that information manage to market the AMM4LV (knowledge) in accordance with their initiatives. This has the potential to enlarge the sources available in educational materials, especially for the community of LV learners.

7.6 Limitations and Recommendations for Future Works

This study limits AMM4LV to (i) the Affective four dimensional design principles and (ii) the AMM4LV prototype. The following subsections explain the limitation:

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7.6.1 Affective Four Dimensional Design Principles

This study utilized a number of different approaches, including comparative analysis, elicitation works, and the UCD technique, to build the affective four dimensional design principles based on the components and elements. Based on the findings of the study, this study was able to identify several recurring themes in the design of mobile applications and compile a comprehensive list of the problems of mobile applications. The data was collected to locate the affective features to meet the needs of LV students. However, the existing mobile applications are not comprehensive, as some of the mobile applications are in the form of figures or images of the prototype.

Comparing the current mobile applications today could lead to new standards in mobile application development.

In this study, the design principles gleaned from the comparative analysis and elicitation works involving LV students, teachers, and academicians are strengthened using the UCD approach. However, this research adapts it to a new context. Hence, this study hope to be able act as a guideline for the researcher to construct a model for affective design principles in developing multimedia content specifically designed for LV learners.

In addition, the affective four dimensional design principles function as a kind of generic design guideline that can be used as a point of departure for creating the AMM4LV for any academic subject aimed towards LV students. In the future, it may be possible to build a subject-specific AMM4LV, which would incorporate affective four dimensional design principles into the framework of inclusive classroom layouts for students with special needs.

7.6.2 The AMM4LV Prototype

As elaborated in Chapter 5, prototyping is one of the methods used to validate the proposed effective design principles. More developers are encouraged to use the Affective four dimensional design principles in the future. The involvement of teachers themselves as developers are most welcome as they are involved in the UCD cycles and could be the developer for developing the AMM4LV. Additionally, the researcher should add more than one learning content for AMM4LV such as adding up many levels of topics and activities.

Besides, the AMM4LV runs on the tablet. In fact, in the interview, most of the subjects are comfortable using mobile device such as tablets during user experience testing. This can trigger their interest while learning.

In addition, learning material such as AMM4LV is also believed to facilitate LV learners with learning ability. Accordingly, studies to explore the use as an affective learning environment are necessary. So, AMM4LV could be considered one of the affective learning materials.

7.7 Summary

To propose a set of affective four dimensional design principles for AMM4LV, this study conducted a thorough and systematic investigation. The proposed affective four dimensional design principles underwent extensive scrutiny from industry experts and were validated through prototype development. The results suggested numerous advantages for the AMM4LV that evolved using the proposed affective four dimensional design principles. These advantages include:

- The proposed affective four dimensional design principles are useful as a guideline to the developer to develop AMM4LV.
- The proposed affective four dimensional design principles are useful in assisting the LV learners to memorize the navigation and motivate them to prolong to use of the AMM4LV for their lesson until the end.
- The proposed affective four dimensional design principles are useful in arousing interest and creating happiness through their experience with the AMM4LV.

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- The proposed Affective four dimensional design principles are useful in engaging with the LV learners to have a positive perception and create a positive mind state in their thought while interacting with the AMM4LV.
- The proposed Affective four dimensional design principles is useful in navigating and interacting with the LV learners despite their limitation of action due to visual limitation.

The learning material should be as assistance for the LV learners to conduct their self- learning without any help from others as they also deserve to have an equal brighter future life as normal learners.

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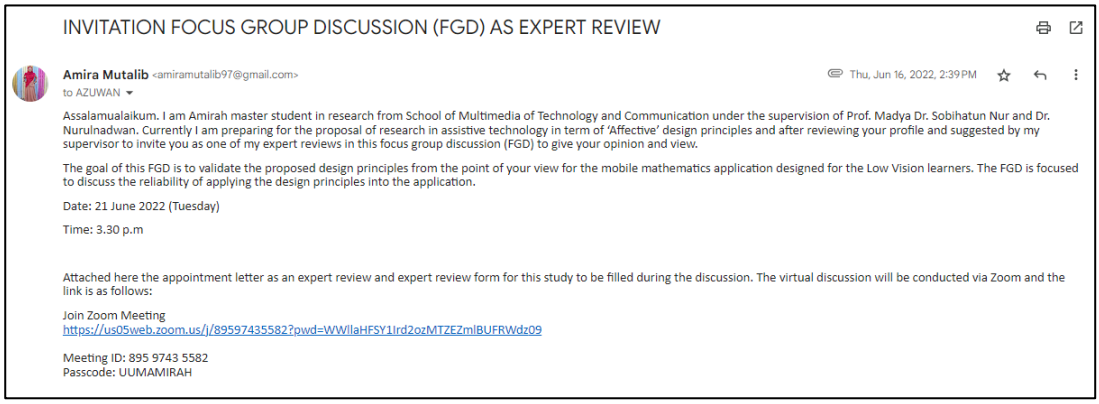
APPENDIX A



INVITATION FOCUS GROUP DISCUSSION (FGD) AS EXPERT REVIEW

Amira Mutalib <amiramutalib97@gmail.com> Thu, Jun 16, 2022, 2:39 PM

to AZUWAN

Assalamualaikum. I am Amirah master student in research from School of Multimedia of Technology and Communication under the supervision of Prof. Madya Dr. Sobihatun Nur and Dr. Nurulnadwan. Currently I am preparing for the proposal of research in assistive technology in term of 'Affective' design principles and after reviewing your profile and suggested by my supervisor to invite you as one of my expert reviews in this focus group discussion (FGD) to give your opinion and view.

The goal of this FGD is to validate the proposed design principles from the point of your view for the mobile mathematics application designed for the Low Vision learners. The FGD is focused to discuss the reliability of applying the design principles into the application.

Date: 21 June 2022 (Tuesday)

Time: 3.30 p.m

Attached here the appointment letter as an expert review and expert review form for this study to be filled during the discussion. The virtual discussion will be conducted via Zoom and the link is as follows:

Join Zoom Meeting
https://us05web.zoom.us/j/89597435582?pwd=WWllaHF5Y1Ird2ozMTZEZmlBUFRWdz09

Meeting ID: 895 9743 5582
Passcode: UUMAMIRAH

Universiti Utara Malaysia

APPENDIX B

Consent Form of Expert Reviewer for "Affective four dimensional Design Principles of Mobile Mathematics for Low Vision (AMM4LV) Learners"

1. I have accepted the official appointment letter from UUM. With the expertise and the existing knowledge that I have, I volunteer to be an expert reviewer for "Affective four dimensional Design Principles of Mobile Mathematics for Low Vision (AMM4LV) Learners" proposed by Nur Amirah binti Abdul Mutalib under supervision of Prof Madya Ts Dr Sobihatun Nur Abdul Salam (UUM) and Ts Dr Nurulnadwan Aziz (UiTM).

2. I understand that the expert review process is designed to gather information and comments in improving the proposed model.

3. I understand that no part of the proposed model may be reproduced, stored in retrieved system, or transmitted in any form or by any means, electronic, mechanical photocopying, recording, or otherwise without prior permission from the researcher and her supervisors.

4. I understand that the researcher will not identify me by name in any report using information obtained from the questionnaire, and that my confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

5. I have read and understood the explanation provided by me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

6. I am given a copy of this consent form.

Expert Reviewer Signature & Official Stamp	**Date**

Universiti Utara Malaysia

APPENDIX C

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

Our. Ref. : UUM/CAS/SMMTC/P-48
Date : 20th June 2022

Mr. Amir Ikhwanuddin bin Sharifuddin
SK Pendidikan Khas Jalan Batu,
Jalan Raja Laut,
50350, Kuala Lumpur.

Sir,

APPOINTMENT AS EXPERT REVIEWER FOR "AFFECTIVE 4-DIMENSIONAL DESIGN PRINCIPLE OF MOBILE MATHEMATICS FOR LOW VISION (AMM4LV) LEARNERS"

Thank you for agreeing to involve as an expert in a Master study with the following details:

Student Name	**: Nur Amirah binti Abdul Mutalib**
No. Matrix	**: 827248**
School	**: Multimedia Technology and Communication, Universiti Utara Malaysia**
Research Title	**: Affective 4-Dimensional Design Principle of Mobile Mathematics for Low Vision (AMM4LV) Learners**
Supervisor	**: Associate Prof. Ts. Dr. Sobihatun Nur binti Abdul Salam and Ts. Dr. Nurulnadwan binti Aziz.**

For your information, the student will use the design principles for her research and needs your expertise to review the proposed model in a few dimensions as stated in the reviewing form.

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Your cooperation, time, and assistance are greatly appreciated.

Thank you.

"WAWASAN KEMAKMURAN BERSAMA 2030"
"KEDAH SEJAHTERA-NIKMAT UNTUK SEMUA"
"KNOWLEDGE, VIRTUE, SERVICE"

Sincerely,

ASSOC. PROF. DR. NORSIAH ABDUL HAMID
Dean
School of Multimedia Technology and Communication
Tel. : 04-9285800 Faks : 04-9285804
HP : 012-4098927 Emel : nor1911@uum.edu.my

APPENDIX D

Button sound/ Character Script

1. Hai! Nama saya Alisha. Jom belajar matematik Bersama- sama!

2. Darab

3. Konsep

4. Latihan

5. Menu Utama

6. Ulang semula

7. Sila masukkan ayat matematik yang betul

8. Sila masukkan objek ke dalam kumpulan mengikut ayat matematik yang diberikan

9. Sila tekan jawapan yang betul

Concept Video Script

1. Cuba lihat dalam gambar rajah ini, terdapat 3 kumpulan belon. Dan setiap kumpulan mempunyai bilangan belon yang sama banyak.

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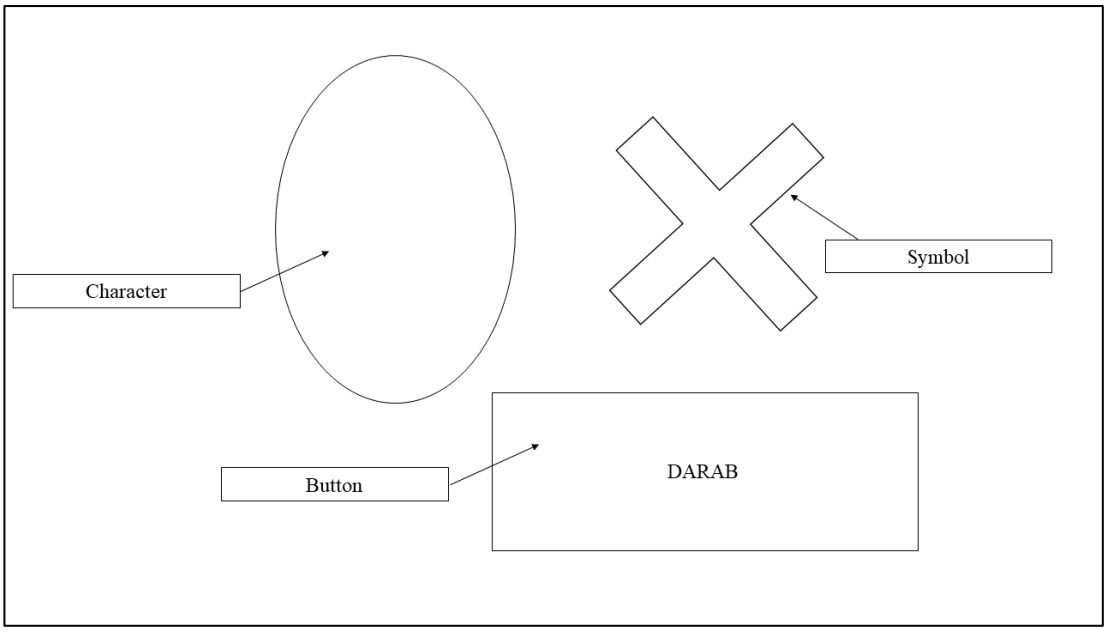
2. Jadi kita lihat 3 darab 2 sama dengan 6

3. Dan satu lagi 2 darab 3 sama dengan 6
Jadi ayat matematik yang mana satukah yang betul?
4. Ini merupakan ayat matematik untuk operasi darab
5. Kita perlu ingat bahawa kotak yang pertama merupakan 'bilangan kumpulan'
6. Kotak yang seterusnya adalah 'Bilangan objek dalam kumpulan',
7. Manakala yang terakhir adalah jumlah objek
8. Jom kita lihat gambar rajah, ini kumpulan, kumpulan , kumpulan
9. Jadi disini terdapat 3 kumpulan belon.1…2…3..
10. Manakala bilangan objek dalam kumpulan terdapat 2 biji belon dalam setiap kumpulan. 2…2…2…Jumlah semua belon adalah 1..2..3..4..5..6
11. Jadi…. ayat matematik yang betul adalah 3 darab 2 sama dengan 6
3 adalah kumpulan, 2 adalah bilangan belon dalam kumpulan dan 6 adalah jumlah ke semuaaaa belon

APPENDIX E



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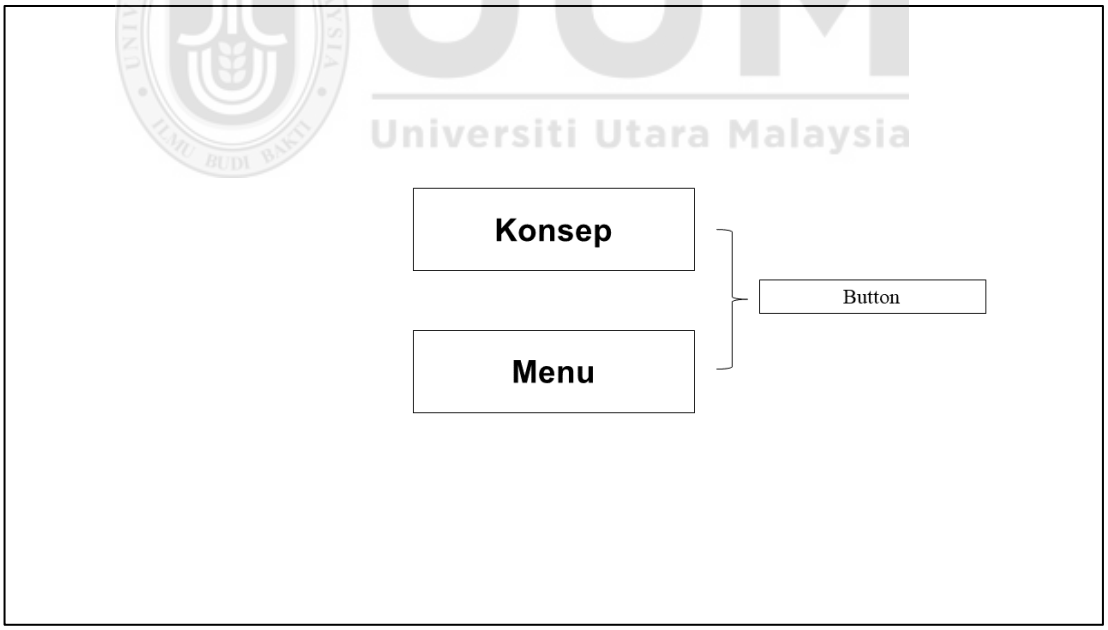

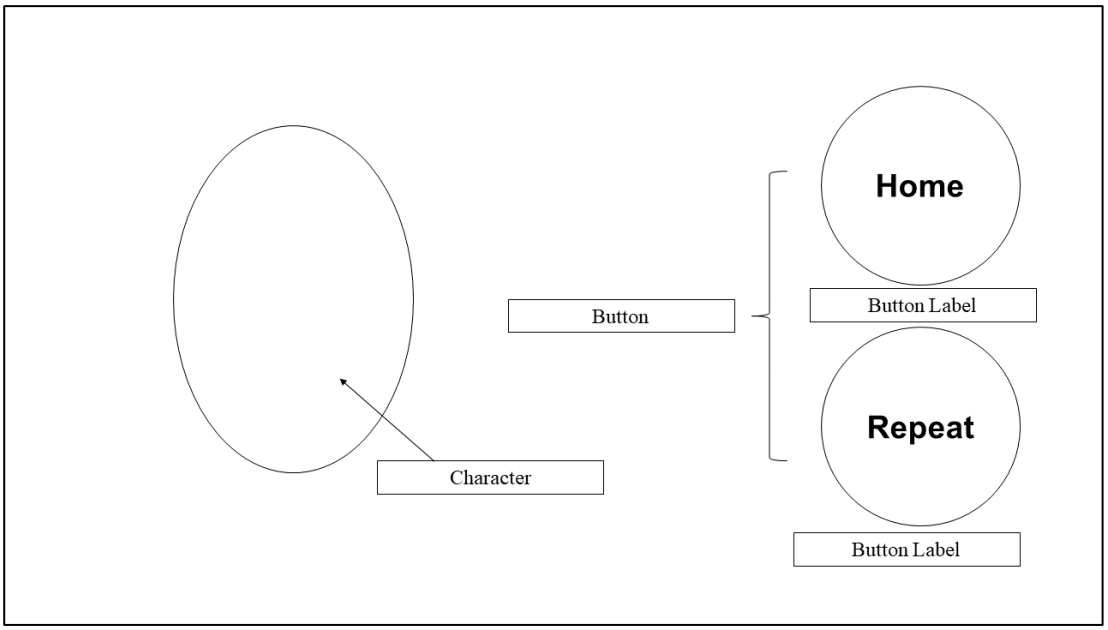

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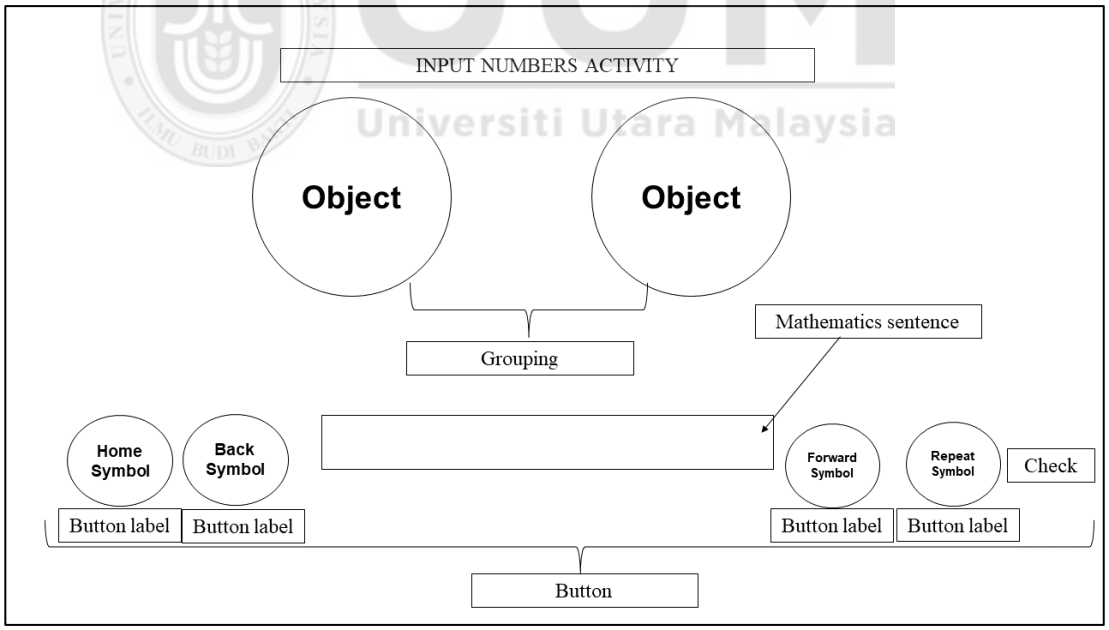

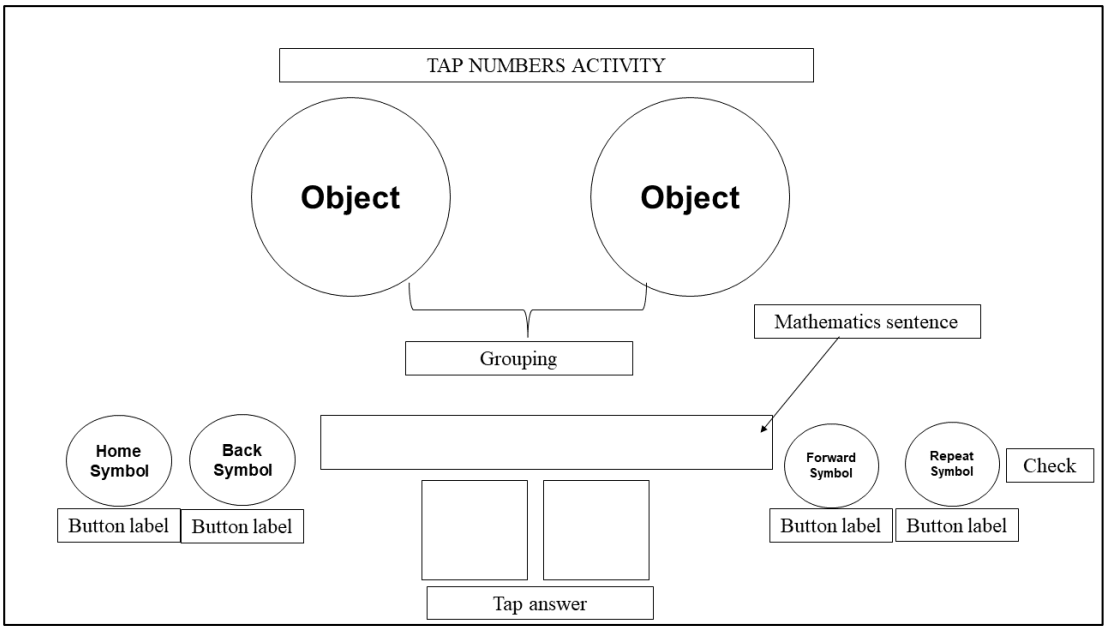

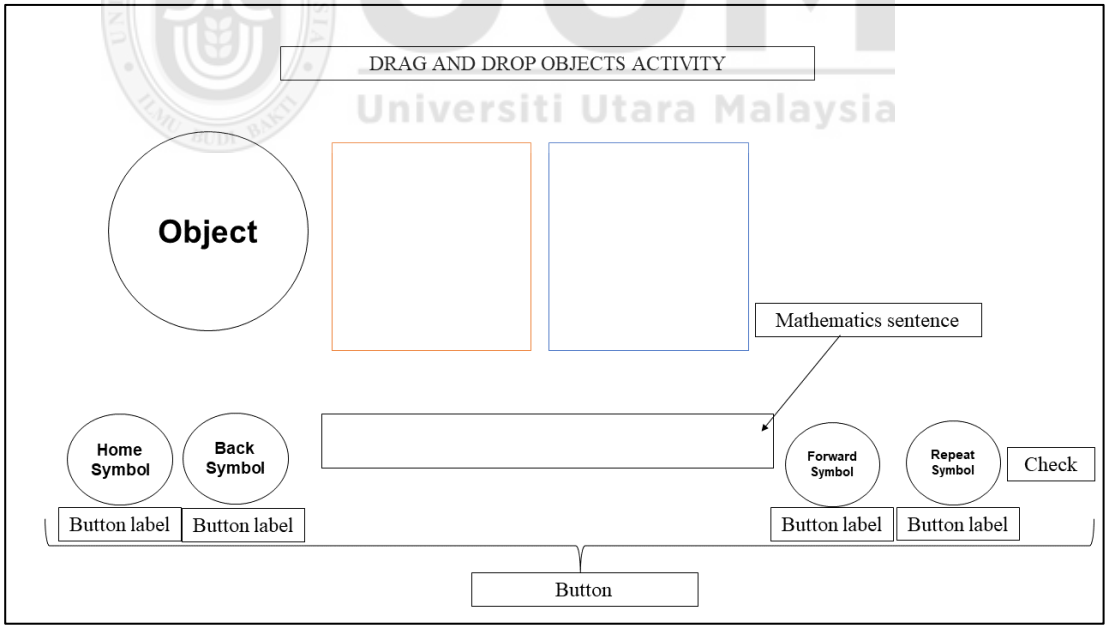

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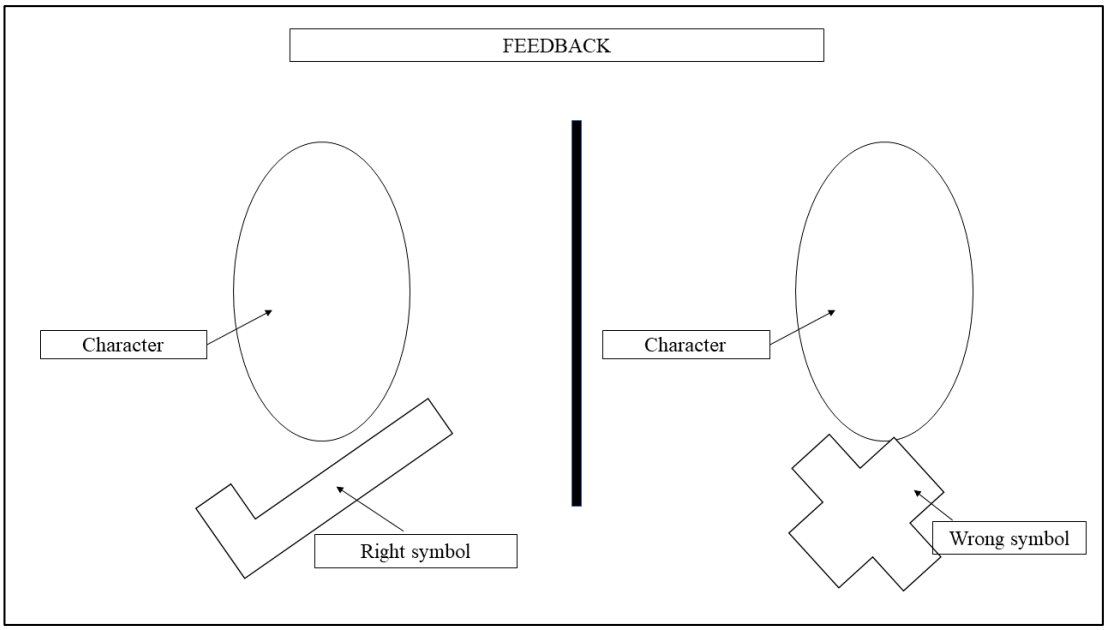

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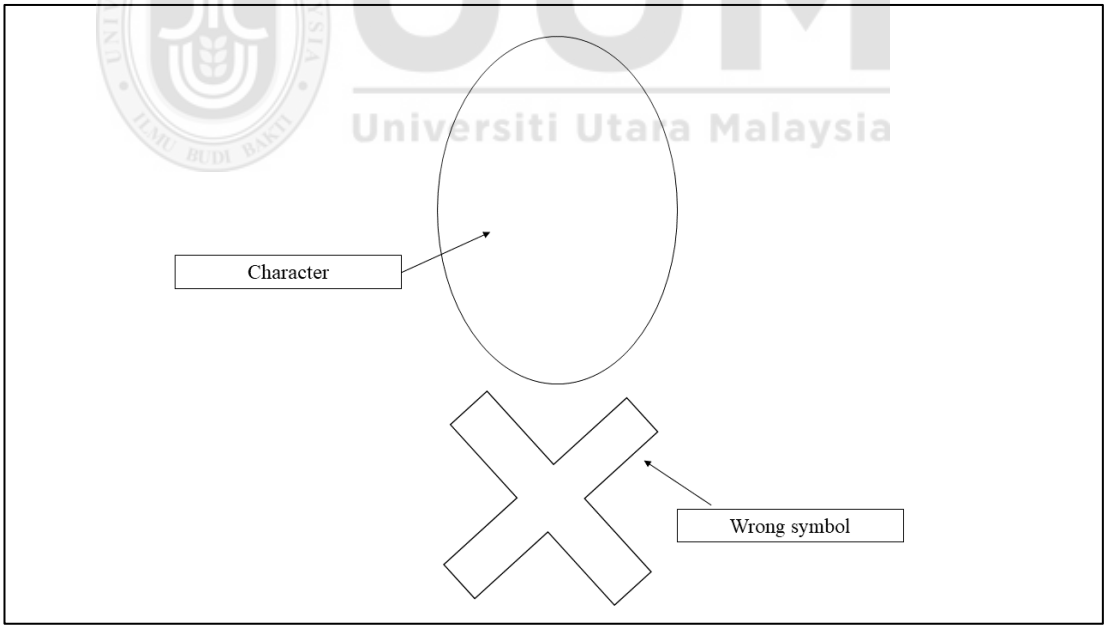

APPENDIX F

LAMPIRAN A

MAKLUMAT KAJIAN

Tajuk Kajian : Prinsip Reka Bentuk 4-Dimensi Afektif Matematik Mudah Alih untuk Murid Berenglihatan Terhad (Affective 4-Dimensional Design Principles of Mobile Mathematics for Low Vision (AMM4LV) Learners)

Nama Penyelidik:
Nur Amirah binti Abdul Mutalib (UUM)

Nama Penyelia:
Prof Madya Ts. Dr. Sobihatun Nur binti Abdul Salam (UUM)
Ts. Dr. Nurulnadwan binti Aziz (UiTM)

PENGENALAN

Anak Tuan/ Puan adalah dipelawa untuk menyertai kajian penggunaan aplikasi matematik yang dibangunkan khusus untuk murid berpenglihatan terhad. Penyertaan ini adalah secara sukarela.

Adalah penting bagi Tuan/ Puan membaca dan memahami maklumat kajian sebelum Tuan/ Puan bersetuju untuk membenarkan anak Tuan/ Puan menyertai kajian ini.

Penyertaan anak Tuan/ Puan di dalam kajian ini dijangka mengambil masa selama tiga sesi di dalam waktu persekolahan.

TUJUAN KAJIAN

Kajian ini bertujuan mengkaji kandungan multimedia yang bersesuaian untuk murid berpenglihatan terhad bagi meningkatkan kefahaman dalam matapelajaran matematik. Hal ini kerana matapelajaran matematik dilihat sangat susah untuk difahami jika hanya menggunakan buku teks sahaja. Penggunaan aplikasi ini dapat menarik minat murid dan meningkatkan keseronokan ketika belajar.

KELAYAKAN PENYERTAAN

Kajian ini akan melibatkan murid berpenglihatan terhad yang berumur 7 hingga 12 tahun.

PROSEDUR KAJIAN

1. Kajian akan dilakukan di dalam bilik darjah pada waktu persekolahan.
2. Murid akan dibekalkan dengan tablet dan diberikan masa untuk menggunakan aplikasi kajian tersebut.
3. Setiap tingkah laku murid akan direkodkan bagi tujuan kajian.

RISIKO

Tiada jangkaan risiko kerana kajian ini akan dijalankan secara pengawasan penuh dari guru dan penyelidik.

PENYERTAAN DALAM KAJIAN

Penyertaan anak Tuan/ Puan dalam kajian ini adalah secara sukarela.

Universiti Utara Malaysia

MANFAAT YANG MUNGKIN [Manfaat terhadap Individu, Masyarakat, Universiti]

Kajian ini akan diberikan kepada anak Tuan/ Puan tanpa kos. Murid yang menyertai kajian ini akan menggunakan aplikasi pembelajaran khas yang direka untuk membantu murid berpenglihatan terhad lebih mudah mempelajari serta memahami matapelajaran matematik.

Hasil kajian ini diharapkan, dapat memberi manfaat kepada komuniti murid berpenglihatan terhad dalam menggunakan aplikasi khas bagi menarik minat serta meningkatkan tahap kefahaman dalam mempelajari matapelajaran matematik

Sijil penyertaan akan diberikan kepada anak Tuan/ Puan setelah selesai menyertai kajian ini.

PERTANYAAN

Sekiranya Tuan/ Puan mempunyai sebarang kemusykilan berkenaan prosedur kajian ini Tuan/ Puan, sila hubungi;

Nur Amirah binti Abdul Mutalib
No. matrik: 827248
Pusat Pengajian Teknologi Multimedia dan Komunikasi
Universiti Utara Malaysia
019-5025953

KERAHSIAAN

Maklumat yang Tuan/ Puan berikan akan dirahsiakan oleh penyelidik. Ianya tidak akan dedahkan secara umum melainkan jika ia dikehendaki oleh undang-undang.

Data yang diperolehi dari kajian ini tidak akan mengenalpasti anak Tuan/ Puan secara perseorangan. Hasil kajian mungkin akan diterbitkan untuk tujuan perkongsian ilmu.

Semua borang kajian dan data anak Tuan/ Puan berikan yang asal mungkin akan disemak oleh pihak penyelidik, Lembaga Etika kajian ini dan pihak berkuasa regulatori bagi tujuan mengesahkan prosedur dan/atau data kajian. Maklumat Tuan/ Puan akan disimpan secara digital dan hanya penyelidik yang dibolehkan sahaja dibenarkan untuk mendapatkan dan memproses data tersebut.

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

HALAMAN TANDATANGAN

Sekiranya Tuan/ Puan bersetuju membenarkan anak Tuan/ Puan menyertai kajian ini, sila lengkapkan Borang Keizinan Peserta di **LAMPIRAN S** dan **LAMPIRAN P**.

Universiti Utara Malaysia

LAMPIRAN S

Borang Keizinan Peserta

(Halaman Tandatangan)

Tajuk Kajian: **Prinsip Reka Bentuk 4-Dimensi Afektif Matematik Mudah Alih untuk Murid Berpenglihatan Terhad**

Nama Penyelidik: Nur Amirah binti Abdul Mutalib

Untuk menyertai kajian ini, Tuan/ Puan atau Penjaga mesti menandatangani mukasurat ini. Dengan menandatangani mukasurat ini, saya mengesahkan yang berikut:

- Saya telah membaca semua maklumat di atas dan saya telah pun diberi masa yang mencukupi untuk mempertimbangkan maklumat tersebut.
- Saya, secara sukarela, bersetuju membenarkan anak saya menyertai kajian ini.
- Saya boleh menamatkan penyertaan anak saya dalam kajian ini pada bila -bila masa.
- Saya akan menerima satu salinan Borang Maklumat dan Keizinan Peserta untuk simpanan peribadi saya.

Nama Peserta/ Murid

No. Kad Pengenalan Peserta/ Murid

Tandatangan Ibu Bapa/ Penjaga **Tarikh:**

Nama & Tandatangan Guru Kelas **Tarikh:**

Nama dan Tandatangan Guru Besar **Tarikh:**

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

Universiti Utara Malaysia

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

Tajuk Kajian: **Prinsip Reka Bentuk 4-Dimensi Afektif Matematik Mudah Alih untuk Murid Berpenglihatan Terhad**

Nama Penyelidik: Nur Amirah binti Abdul Mutalib

Untuk menyertai kajian ini, Tuan/ Puan atau penjaga mesti menandatangani mukasurat ini.

Dengan menandatangani mukasurat ini, saya memahami yang berikut:

- 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 ahli akademik.
- Bahan tersebut juga akan dilampirkan pada laman web jurnal di seluruh dunia. Sesetengah laman web ini bebas dikunjungi oleh semua orang.
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- 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.

Nama Peserta/ Murid **Tarikh:**

No. Kad Pengenalan Peserta

Nama & Tandatangan Ibu Bapa/ Penjaga **Tarikh:**

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

APPENDIX G

KEMENTERIAN PENDIDIKAN MALAYSIA
BAHAGIAN PENDIDIKAN KHAS
ARAS 2, BLOK E2,
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
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Ruj. Kami : KPM.600-2/1/4 Jld. 6 (28)
Tarikh : 09 Mei 2022

Nur Amirah binti Mutalib
No. 49, Kg. Langgok
Jeneri
08320 Sik
KEDAH

Puan,

PERMOHONAN UNTUK MENJALANKAN KAJIAN PENYELIDIKAN BERTAJUK "AFFECTIVE 4-DIMENSIONAL DESIGN PRINCIPLES OF MOBILE MATHEMATICS FOR LOW VISION (AMM4LV) LEARNERS"

Dengan hormatnya saya merujuk perkara di atas dan surat daripada Bahagian Perancangan dan Penyelidikan Pendidikan [Rujukan: KPM.600-3/2/3-eras(12446)] bertarikh 26 April 2022 adalah berkaitan.

2. Sukacita dimaklumkan bahawa Bahagian Pendidikan Khas (BPKhas), Kementerian Pendidikan Malaysia (KPM) tiada halangan untuk membenarkan puan menjalankan kajian bertajuk **"Affective 4-Dimensional Design Principles of Mobile Mathematics for Low Vision (AMM4LV) Learners."**

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

3.1. Penyertaan murid dan guru dalam kajian adalah secara sukarela;

3.2. Menjalankan aktiviti kajian di luar waktu PdP; dan

3.3. Tidak menyentuh perkara yang bertentangan dengan Dasar Pendidikan Negara serta isu-isu sensitif peribadi murid berkeperluan khas dan keluarga mereka.

...3/-

4. Surat kelulusan ini sah digunakan bermula dari **tarikh surat ini dikeluarkan hingga 19 September 2022**. Walau bagaimanapun, kelulusan ini turut bergantung kepada kebenaran Guru Besar sekolah dan ibu bapa/penjaga murid yang berkenaan.

5. BPKhas juga berharap agar puan dapat mengemukakan senaskah laporan akhir kajian berkenaan setelah kajian tersebut disiapkan untuk rujukan dan simpanan Bahagian ini.

Sekian, terima kasih.

"WAWASAN KEMAKMURAN BERSAMA 2030"

"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah,

(HAJAH SALMAH BINTI JOPRI)
Pengarah
Bahagian Pendidikan Khas
b.p. Ketua Setiausaha
Kementerian Pendidikan Malaysia

PC/Masitah/desktop/Dr.Rozaniza/Kelulusan Kajian_Nur Amirah Mutalib

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APPENDIX H

Component	Design Principles	Interview Question	Quotation
Emotion	Consistency	Do you feel easy to remember the navigation in This application? (Memorable)	
	Good color contrast	Was the color distracting or interesting? (Motivational)	
Feeling	Clear and symmetrical layout	What do you feel for the first time looking to the AMM4LV? (Interest)	
	Landscape orientation	Do you like the orientation? (Interest)	
	Imitates children voice intonation	Do you understand the explanation/ instruction in the video? (Happiness)	
	Human character	What do you feel about the character?(Happiness)	
Thought	Button label	Do you think you understand the button function? (Positive perception)	
	Large font	Did the font large enough? (Positive mind state)	
	Highly contrast of interface components	Do you think you can use this application alone without help? (Positive mind state)	
Action	Place button at the edge	Do you feel easy navigating the AMM4LV? (Navigation)	
	Feedback of action	Was it easy to interact with AMM4LV? (Interaction)	
	Error Handling		

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