3D INTERACTIVE ANIMATION LEARNING FOR DYSLEXIC CHILDREN

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FACULTY OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY
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FACULTY OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY
UNIVERSITY OF MALAYA
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2018

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ABSTRACT

Dyslexia children are known as having difficulties to learn letters and numbers due to their brain inability to interpret objects into letters and words. Their abnormal interpretation of letters and words compared to normal children abstained themselves from long words and sentences. This inability caused problems in mastering reading and writing skills. To date, numerous studies have focused on developing or inventing learning aids in the format of realis or authentic materials for dyslexia children. Studies also have documented the remarkable progress of dyslexia children of whom turned out to be Information Communication Technology (ICT) literate when they grew up. This development signifies the ability of ICT in unburying and molding the talent of dyslexia children. Today's development in multimedia software and hardware is a new hope for these children in mastering literacy skills. However, despite the research and technological innovation outcomes, effort to benefit their ICT inclination by integrating their learning with ICT elements is still sparse. This study attempts to aid the learning process of dyslexia children via 3D tool, named ThreeDLexic. Focusing on specific 3D alphabets which was identified from a 3-month pilot project held at the research center for PDM (Persatuan Dyslexia Malaysia), a 3-month observation was conducted on 174 participants to obtain the data. Once the application is ready, a three month observations will also be conducted at the same center. 3D and dyslexia children are inter-related. So it is very hopeful that the application of 3D will be highly beneficial in the learning process of children with dyslexia.

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ABSTRAK

Kanak-kanak disleksia atau dikenali juga sebagai mengalami kesukaran untuk belajar huruf dan nombor kerana ketidakupayaan otak mereka untuk mentafsirkan objek ke dalam huruf dan kata-kata. Tafsiran huruf dan kata-kata mereka yang berbeza berbanding dengan kanak-kanak biasa menyebabkan mereka tidak berminat dengan perkataan dan ayat yang panjang. Perbezaan ini menyebabkan masalah menguasai kemahiran membaca dan menulis dalam kalangan mereka. Sehingga kini, banyak kajian menumpukan kepada pembangunan atau penciptaan alat bantu pembelajaran dalam format bahan realis atau sah untuk kanak-kanak disleksia. Kajian juga telah mendokumenkan kemajuan yang luar biasa kanak-kanak disleksia yang menjadi celik Teknologi Maklumat dan Komunikasi (TMK) ketika mereka dibesarkan. Perkembangan ini menandakan keupayaan TMK membentuk bakat kanak-kanak disleksia. Perkembangan hari ini dalam perisian multimedia dan perkakasan adalah harapan baru untuk kanak-kanak ini dalam menguasai kemahiran membaca. Walau bagaimanapun, hasil penyelidikan dan inovasi teknologi, usaha untuk memanfaatkan kecenderungan ICT mereka dengan mengintegrasikan pembelajaran mereka dengan elemen TMK masih jarang berlaku. Kajian ini cuba untuk membantu proses pembelajaran kanak-kanak disleksia melalui elemen multimedia tiga dimensi (3D), yang dinamakan ThreeDLexic. Memfokuskan pada huruf 3D spesifik yang dikenal pasti dari projek percubaan selama 3 bulan yang diadakan di pusat penyelidikan PDM (Persatuan Dyslexia Malaysia), pemerhatian 3 bulan dilakukan pada 174 peserta untuk memperoleh data. Sebaik sahaja penyelidikan ini siap, pemerhatian tiga bulan juga akan dijalankan di pusat yang sama. Kanak-kanak disleksia dan 3D mempunyai perkaitan antara satu sama lain. Oleh itu, sdiharapkan bahawa penggunaan 3D dapat memberi manfaat dalam proses pembelajaran kanak-kanak disleksia.

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University of Malaya

TABLE OF CONTENTS

University of Malaya

University of Malaya

University of Malaya

CHAPTER 3: RESEARCH METHODOLOGY

CHAPTER 4: DATA COLLECTION AND ANALYSIS

University of Malaya

University of Malaya

University of Malaya

University of Malaya

LIST OF FIGURES

University of Malaya

University of Malaya

University of Malaya

University of Malaya

LIST OF TABLES

University of Malaya

University of Malaya

List of Symbols and Abbreviations

ABBREVIATIONS	DESCRIPTION
3D	Three Dimensions
2D	Two Dimensions
MOE	Ministry of Education
RQ	Coding for Research Subject
FDM	Fuzzy Delphi Method
PDM	Persatuan Dyslexia Malaysia
NGO	Non-Government Organization
ThreeDLexic	Three Dimensions Lexic

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University of Malaya

TABLE OF APPENDICES

University of Malaya

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Dyslexia is derived from Greek. “Dys” means without, not adequate or difficulty and lexis/lexia means words or language. Dyslexia is one of the characteristics of learning difficulties in children who have problems in written language, oral, expressive or receptive (Ely et al. 2014). Often regarded as an interference with the ability to read, dyslexia can also be translated as a learning disability that specifically affect a person's ability to learn how to read and understand a language very well (Marshall, 2016), including the inability to write well. In other words, dyslexia has been considered as a disruption in the ability to learn, not only in reading.

Dyslexia has been around for a long time and is very common in the community. According to International Dyslexia (2012), 15% - 20% of world population are affected by dyslexia (Rello, 2014). In Malaysia, a study by Special Education Department of the Education Ministry estimated that there were 314000 school-going children in Malaysia affected by dyslexia (Vijayaletchumy & Subramaniam, 2013). Ministry of Education's Parliamentary Secretary Komala Devi (2004) also reported that there were an estimated of 5% dyslexia cases found in various community or one (1) out of every twenty (20) students. These figures are very high compared to Down-

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Syndrome, one (1) for every six hundred (600), and Spastics, one for every seven hundred (700).

Based on a study conducted by The Malaysian Social Harmony Society Nordin Ahmad (2005), it was established that an estimated of 10% - 15% primary school children in Malaysia are affected by dyslexia and a majority of them are Malays.

Although there have been various researches and studies on dyslexia, there are still many people who do not understand the condition well. Contrary to popular belief, dyslexia is not a stage of learning disability experienced by children at a certain age. Dyslexia is a lifelong condition, and can be very severe to the learner.

1.2 PROBLEM STATEMENT

It is profoundly accepted that before a child can master literacy skills (reading & writing) he/she needs to identify the alphabets well. Normally, dyslexic children have difficulties in identifying several alphabets. According to (Sd, 2010) spelling stresses a child's short and long-term memory and is complicated by the ease or difficulty the child has in writing the letters, legibly and in the proper order.

The readily available and widely use of various types of mobile communication appliances have very beneficial in many fields including educations, sports,

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entertainment, economy and medical. Education has also benefit significantly, as seen in the widely used of devices such as laptops, net-books, note-books, tablets, smart-phones and LCDs in schools in Malaysia. Even most parents are using these devices as a medium of learning and entertainment for their children. With all advancements widely used and many readily available devices using android platform, it is an opportunity to exploit the technology that will benefit dyslexia pupils.

Apart from that, the learning of a native language is claimed as crucial as it plays a vital role to help children survive in their communication skill for the benefit of their future life. Not only write, dyslexic children also found to be left behind in terms of their communication skill in the native language. This is a worrying scenario for the local education system.

Throughout my literature review in the relevant body of literature pertaining to dyslexic children and the potential of educational technology, the user-friendly features of mobile technology appliances have benefitted many fields including education, sports, entertainment, economy and medical. In particular, education has benefitted significantly; the technology embedded in laptops, net-books, tablets, smart-phones and LCDs in schools in Malaysia are mobile devices that have assisted the acceleration of learning. Even most parents are using these devices as a medium of learning and entertainment for their children.

Thus far, my review on the body of literature pertaining to 2D have paved me to see the potential of the 3D technology in achieving better results for the children

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Although beneficial, interactive animation using 2D concept is less attractive and simulative as compared to 3D. Researcher contend that presenting problematic and reversal letters such as b;d,m;w, and s;z in 3D concept may help their brain to accurately identify those letters withous less confusion. As many scholars advocated, it is important for students with dyslexia to encourage learning in the manner they want.

Additionally, there are evidences that android-based application can be used as an adaptation to further enhance this present research. Due to all the advancement that an adroid platform offer in most of the devices, researchers found that they represent opportunities to be manipulated for the benefit of dyslexic children.

Therefore, this research seeks to explore the needful aspects in developing a 3D prototype to assist children in learning. In other words, it aims to study on how we can properly utilize 3D android based devices so that they can use this application independently to identify and write letters.

The teaching content in the ThreeDLexic, the tool developed, uses Bahasa Malaysia as it is the foundation in reading and writing for Malaysian school children. Currently the number of research performed which focused on teaching dyslexic children in Bahasa Malaysia using 3D concept, is very limited though there are claims saying that this learning style is fun, easy, and able to assist the children in understanding more of the

University of Malaya

content. It is important for students with dyslexia to encourage learning in the manner they want (Ronaldi Saleh Umar, 2011).

1.3 RESEARCH OBJECTIVES

1. To investigate the extent to which the reading difficulties of dyslexia children registered with the Society of Dyslexia Malaysia (PDM), in relation to the reading difficulties faced by global dyslexic children found in literature.
2. To review on the extent to which technology has thus far being applied and has helped the reading skill in dyslexic children in Malaysia.
3. To develop an android-based 3D animated assistive-reading software for dyslexic children.
4. To evaluate quantitatively and qualitatively the extent to which the developed 3D animated assistive-reading software can assist dyslexic children with their difficulty to correctly identify the reversal letters.

1.4 RESEARCH QUESTIONS

1. What are the problematic alphabets particularly the reversal letters demonstrated by dyslexic children in their learning?
2. To what extent the existing technology-aided intervention has helped improve the reading and writing skill among the dyslexic children in Malaysia, thus far?
3. To what extent the developed 3D animated assistive-reading software can assist dyslexic children with their difficulty to correctly identify the near-identical letters?

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1.5 RESEARCH AIM

Based on the above discussion, the main goal for this study is to develop an android-based 3D animated assistive-reading software for dyslexic children.

1.6 BRIEF OVERVIEW ON THE DEVELOPED 3D ANIMATED ASSISSTIVE- READING SOFTWARE – THREEDLEXIC

A 3D animated assistive-reading software named ThreeDLexic was developed as an assisted teaching aids, in particular, a reading aid, that is based on android platform using Unity and 3DMax. The target users are dyslexic children ages from 4 to 8 years old at the Society of Dyslexia Malaysia (Persatuan Dyslexia Malaysia). The prototype consists of four main menus including *user guide*, *setting*, *modules* and *developer*. This study evolved around the development and evaluation of 3D animation for dyslexic affected children with difficulty in identifying identical alphabets such as, n:u, p:b, w:m and b:d and other alphabets that fall into the category.

1.7 RESEARCH MOTIVATION

The researchers' experience as a teacher for dyslexic children for 5 years at a government school coupled with three year-experience as a trainer at a National Dyslexic Centre governed by a private NGO has flourished my passion to help these

University of Malaya

children. Dealing with these children has taught researcher to be patient even though it proved a challenge for researcher to keep the spirit high all the time. Soon researcher realized that it is a pathway for researcher to manifest the promise our pledged upon our decision to become a teacher for special need children.

Being a graduate in Science Computer is like the other side of the world from that of the dyslexic children's which demand more humanistic approach. But gradually, mingling with these children have molded researcher to become more equipped with soft skills, of which is priory lacking when researcher dealt with machines and computers during researcher first degree.

Having difficulties in teaching them to recognize alphabets and then to write became both my stress and passion. Researcher never stopped thinking how to assist these children to learn (read and write) better. Researcher read and referred to many books, articles and studies. Until researcher came to realize that it's already in 'researcher'- the skills and expertise!

With this contentment and motivation, researcher found 'myself' embarking on this journey to develop a software using a 3D-assisted technology as to help researchers' children and other dyslexic children.

University of Malaya

1.8 RESEARCH CONTRIBUTION

This research may not be able to address the issue of illiterate in Malaysia in a large scale. However, it is hoped that, throughout time, it may be of beneficial for relevant authorities in increasing the literacy percentages of students in Year One, Year Two and Year Three. This is in line with government agenda to increase the literacy rate by the year 2020 and in accordance with the current National Transformation (TN50) whereby one of the targets is to achieve a developed country status through the creation of a learning society.

In particular, this research may be beneficial to:

a) Ministry of Education, Malaysia.

b) Pre-school teachers.

c) Dyslexia class teachers.

d) NGOs such as Persatuan Dyslexia Malaysia

e) Parents and dyslexia children.

f) Future researchers.

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1.9 ORGANIZATION OF DISSERTATION

The layout of the dissertation is summarized as follows:

Chapter 1: Introduction

The chapter starts with an of the background of the study, scope, objectives, problem statement, significance of the study and an introduction of the development of the 3D prototype.

Chapter 2 : Literature Review

This chapter discusses the adaptive technique, 3D object learning, learning style of dyslexic children and things related to it. It also covers topics encompassing the current research development in multimedia in education and dyslexic education. The rationale behind using interactive 3D prototype is also discussed and examples of other application that uses the similar methods are elaborated.

Chapter 3 : Research Methodology

The research methodology for the proposed dissertation is discussed in detail in this chapter. It spells out each process involved which encompasses three stages: needs analysis to gather the needs required by the target groups, system development whereby the findings from need analysis stage were used to develop the software, and evaluation phase whereby the software called ThreeDLexic was run and tested to the participants. The modules developed and used in conjunction with the software is also presented and

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discussed. The considerations put forward by the researcher in designing and implementing the adaptive technique to the 3D application is also highlighted.

Chapter 4 : Data Collection and Analysis

This chapter explains step-by-step data collection to navigate the study. It covers the mixed mode (qualitative and quantitative) data collection via observation, Fuzzy Delphi Method and the tests performed using the software.

Chapter 5 : Prototype Design And Development

This chapter describes the steps to develop ThreeDLexic. In particular it explains the system requirements for the software development, to the designing of the interface for end users. The model by which the design was adapted to navigate the software development is also described.

Chapter 6 : Result and Discussion

The analysis of the evaluation is discussed in this chapter. It encompasses the results and discussion for the questionnaire survey and structured interview. User acceptance and satisfaction are part of the significant findings that are detailed out in this chapter, to answer the research questions aiming at achieving the research objectives.

Chapter 7: Summary And Conclusion To The Research

The contributions, achievement, constraints of the study and future enhancements of the research are discussed in this chapter. It brings about the conversation that paved to the evaluation of the objectives achievement.

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CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

This chapter reviews the previous studies related to dyslexic children by focusing on the interventions used to aid their learning process. It tries to bring into conversation the usability and the potential benefits of educational technology and the Information and Communication Technology (ICT) as learning aids for the dyslexic children, specifically in literacy problem. In so doing, previous studies that employed software, digital tools, and the android platform as learning tools (such as Unity and 3dmax) are reviewed to inform the needs to develop such software for dyslexic children. In particular, it tries to justify the development of ThreeDLexic in the present study as an appropriate assistive-reading software for dyslexic children during the digital age. In addition, this chapter will review the existing instructional design model (ID) theories.

2.2 DYSLEXIC CHILDREN

For the past few decades, numerous research on dyslexic children has been carried out globally. Stretching from the western context to the Asia region, Malaysia is not excluded in the rigor of studies to understand the dyslexic children. The trend of studies

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is also changing throughout the decades. In the early 1990s, Society for Neuroscience studies were more focused on the medical sides of the dyslexia whereby it was encountered that about 15% of the world's population may have dyslexia. The finding also points that most of the children were suffering from literacy problems. In particular, they had problems in recognizing alphabets causing them to lag behind in academic compared to their peers (Kast et al., 2011). In the beginning of the research, it was more specific relating to the early 90's medical terms where a general understanding was developed that dyslexic children are those having difficulties in mastering literacy (World Federation of Neurology).

However, it is noted that not all dyslexic children experience similar problems. From studies done during the 19th century, researchers found four etiological types of learning problems that can be used to define dyslexia. These are, perceptual deficits (Hinshelwood, 1917; Orton, 1937), memory deficits (e.g., Liberman, Mann and Shankweiler, 1982; Jorn, 1983), language processing deficits (e.g., Rozin and Gleitman, 1977; Marsh, Freidman and Welsh, 1981), and visual processing deficits (e.g., Lovegrove, Martin and Slaghuis, 1982; Livingstone et al., 1991).

As time passes by, currently in the 21st century, researchers' interest are shifting towards the brain development of the dyslexic children who are having difficulties in mastering literacy (Valdois, Lassus-Sangosse & Lobier, 2012; Leavett, Nash, & Snowling, 2014) and determined that a rather high percentages of dyslexia cases may be genetically contracted.

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In terms of diagnosis, currently, it is very difficult to detect children suffering from dyslexia unless substantive co-operation is given by parents who recognize the oddity in their children's behavior (Leavett et al., 2014). Interestingly, it was acknowledged that dyslexia is not only suffered by ordinary children but may also be suffered by those with high intelligence quotient (IQ).

With the rapid growth in medical technologies, diagnosis is more scientific with the availability of studies on the differences between dyslexic and normal brain. By using diagnostic imaging, it is proven that dyslexia is associated with the problem of nervous systems connecting the two hemisphere of dyslexic brain, which is named as corpus callosum (Health, 2003). Noteworthy, it is not related to fast or slow learners nor to remedial or brilliant children.

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2.3 DIFFICULTIES FACED BY DYSLEXIC CHILDREN

For decades, researchers investigate dyslexia as a neurodevelopmental disorder that is characterized by slow and inaccurate word recognition. In their work, Peterson & Pennington (2012) and Norton and his colleagues (Norton, Beach & Gabrieli, 2015) claimed as dyslexia is one of the most common learning disabilities, yet its brain basis and core causes are not yet fully understood. There are three stages of difficulties faced by dyslexic children which can be categorized based on their age: 5 years old (namely pre-school), 6 to 9 years old and 9 to 12 years old. For instance, among the problems faced by the children of the age between 6 to 9 years old is the tendency to reverse the words known as, mirror-writing or writing in the reversed form. Table 2.1 illustrated the overall segmentations of the problem.

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Table 2.1 : Age Range And Problems Suffered by Dyslexic Pupils (Integrasi, 2011)

Age Range	**Problems**
Pre-school	1. Slow speech skills and difficulties in comprehending instructions. 2. Tendency to replaced words and hyperactive 3. Weakness of hard and soft motor 4. Tendency to forget names of things or subjects learned 5. Never crawl during infancy 6. Like to hear but not reading by themselves 7. Highly curious, interested in new things and very inquisitive
6 to 9 years	1. Weak in reading, writing and spelling skills and have a tendency to reverse words, letters and numbers 2. Using fingers to count and read 3. Confuse between left and right 4. Mirror writing or reverse
9 to 12 years	1. Error in reading, spelling and weak in comprehension 2. Takes a longer time in completing exercises 3. Difficulties in copying information on the whiteboard or textbooks 4. Difficulties in following long verbal instructions 5. Appears untidy whether at school or at home 6. Low esteem and suffers from depression

The image processing of the alphabets or more accurately referred to as the alphabet identification in this study by those suffering from dyslexic abnormalities are very different from those with no dyslexia. This situation is agreed by researchers both locally and internationally (Norton, Beach, & Gabrieli, 2015;Peterson & Pennington 2012;Lidwina, 2012;Subramaniam 2008;Rohaty Mohd. Majzub, 2005). They emphasize that these abnormalities make it difficult for dyslexic people to learn language involving roman letters. Researchers have identified several variations of abnormalities. To name a few, a study by Friedmann and Haddad-Hanna (2014) stated that there are ten types of dyslexia present, while studies by Peterson, Pennington, and Olson (2013) emphasized the abnormalities or difficulties faced by dyslexic over phonology and orthography in

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the language system learned. Prior studies (Harm & Seidenberg, 1999) emphasizes the way phonological acquisition is obtained by dyslexic or non-dyslexic. It can be concluded here that the difficulty to be faced by dyslexic children is closely related to the content of the learning contained in the basic literacy of the Malay language as below. The yearly teaching plan for teaching dyslexic children in the special class encompasses an introduction to the alphabets. It is illustrated in Table 2.2.

Table 2.2 : Yearly Teaching Plan (KPM, 2015)

WEEK	SKILLS AND ACTIVITIES	MODULES/TOOLS
W1 2.1.2013 4.1.2013	1. Small letters from a-z Pronounce/identify names of small letters according to sequence Pronounce/identify names of small letters randomly.	Individual alphabet cards a b c d
W2 7.1.2013 11.1.2013	Find, select and color hidden small letters. Writing small letters with fingers in the air, on the tray and on the sand, on a friend's back and so on.	Alphabets Chart in sequence a b c d e f g h i j k l m n o p q r s t u v w x y z
W3 14.1.2013 18.1.2013	Forming small letters in sequence by using platisin or clay. Copy or draw by using cut out cards in sequence.	Pictured Alphabets Card.

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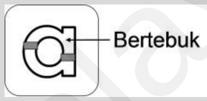
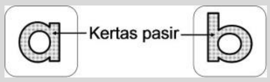
Table 2.3 : Continues: Yearly Teaching Plan (KPM, 2015)

WEEK	SKILLS AND ACTIVITIES	MODULES/TOOLS
W3 14.1.2013 18.1.2013	Cutting small letters in sequence. Copy small letters from small letter cards. Write small letters read by the teacher or a friend or from audio cassete recording.	 Alphabets cut out card  Alphabet Cards from sand paper. 

Meanwhile for children suspected of suffering from dyslexia, one instrument to determine the probability that a student experiences dyslexic named as Dyslexia Review List Instrument used by Education Ministry of Malaysia at all schools in Malaysia is available. This instrument also includes the diagnosis of the predicament of students writing backwards. The list can be found in Appendix H.

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2.4 BAHASA MALAYSIA SUBJECT FOR DYSLEXIC CHILDREN

In Malaysia, children start learning Bahasa Malaysia at the age of 6 years old and continue until higher level. In the early stage of learning, the teaching process revolves around the introduction to alphabets, identifying letters, word syllables and up to the formation of simple sentences. This is a very critical stage whereby children are expected to be able to learn all the 26 letters (from A, B and C until Z) both in small and capital letters. Recognizing the learning difficulties faced by dyslexic children, a special curriculum was developed known as Special Needs Students Program or *Program Murid Berkeperluan Khas* (MBK). It is part of the larger Inclusive Education Program or *Program Pendidikan Inklusif* (PPI).

With regards to studies on literacy problems, a work done by Dani and Subramaniam (2016) has found some reading mistakes by dyslexic children during Bahasa Malaysia reading class. They categorized these mistakes as, inserting, exchanging and deleting mechanism. These mechanism of reading mistakes as stated by Levinson (1994) were done by Malay dyslexics students in this research but transferring, reflecting and evaporating could not be detected (Dani & Subramaniam, 2016).

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Table 2.4 : Examples Of Inserting, Exchanging, Deleting And Sentence Mechanism

Mechanism	Bahasa Malaysia Word		Dyslexic Error
Inserting	makan tulis malam basikal ambi	became	makanan menulis semalam berbasikal mengambil
Exchanging	api buku telur ikan sekolah		apa buka telar akan sekolah
Deleting	pilihan jawatan basikal serupa larangan		pilih jawat basi rupa larang
Sentence	Emak membuat air kopi. Emak menjahit baju. Ayah membaca surat khabar. Kakak membawa buah. Doktor membalut tangan.		Emak kopi. Emak jahit baju. Ayah baca. Kakak buah. Doktor balut tangan.

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2.5 TEACHING DYSLEXIC CHILDREN USING TECHNOLOGY

2.5.1 EDUCATIONAL TECHNOLOGY

Efforts to assist dyslexic children have been going on an international scale particularly in the era of the 21st century. For instance, countries in the European Union have long been using multimedia software (Ronaldi Saleh Umar, 2011) as one of the interventional approaches for dyslexia affected children.

In this regards, Malaysia is not left behind. Interactive Mobile Comics Dyslexia or D-mic (Dyslexia Mobile Interactive Comic) and Tutor Software Dyslexia Visual Phonics, to name a few, are among the software produced by local developers. For instance, the Tutor Software Dyslexia Visual Phonics was developed by Dr. Vijayaletchumy Subramaniam a lecturer at the Faculty of Modern Language and Communication, Universiti Putra Malaysia. Against the backdrop of Levinson theory (1994), this software was developed based on six Ortongillingham Phonogram methods to teach spelling. The software is unique in that it entirely uses Bahasa Melayu, which makes it easier for dyslexic children in Malaysia to understand while unburying their different abilities. Levinson theory (Levinson, 1994 in Rosdi bin Aziz, 2011) states that students with dyslexia may not have the power to remember the letters and combinations of words due to their short-term memory ability. They cannot scan the letter, word or sentence while reading causing them to leave or skip every word they read. Therefore they cannot understand the literature being read because of poor concentration and comprehension in reading. The software is intended to be used by the Ministry of Education, Department of Special Education, Curriculum Development Centre, teachers and parents.

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Apart from that, a group of scholars and researchers from Faculty of Art and Design have collaborated with researchers from Faculty of Education, UiTM to produce an interactive learning tool on a mobile platform for children with dyslexia, known as Interactive Mobile Comics Dyslexia or D-mic (Dyslexia Mobile Interactive Comic).

However, both of the software were developed on a 2D concept. They have similarities, in which both used bright colours and beautiful animation to attract dyslexic children. However, they seemed to neglect the skills that the dyslexic children need.

2.5.2 MULTIMEDIA LEARNING

Multimedia, according to Oxford Dictionary, means the use of a variety of artistic or communicative media. Multimedia learning is a learning process that is facilitated by the advancement of various media. Multimedia learning is informed by numerous theories and models that attempt to articulate how learning is facilitated by the employment of technology.

To inform the present study, theories from Mayer in cognitive multimedia learning context are referred to as it is the most appropriate to illustrate the study's intention to develop a software. The premise of Mayer's cognitive multimedia learning lies in his words: "people learn more deeply from words and pictures than from words alone" (Mayer, 1947). Hence, Mayer proposed a principle known as 'multimedia principle' to help we understand how different forms of information can elevate the digestion of

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information effectively to the learners. However, realizing the danger of simply adding text or graphic without thoughtful considerations, Mayer alarms that adding word to pictures or vice versa, is not all about a multimedia learning. He goes on to emphasis the need to be cautious in incorporating information with the instructions, in the light of how human mind works.

Mayer's cognitive theory of multimedia learning (2002) is based on three main assumptions: there are two separate channels (auditory and visual) for processing information; there is limited channel capacity; and that learning is an active process of filtering, selecting, organizing, and integrating information. The theory, known as The Multimedia Learning Theory (Mayer, 2003) is illustrated in Figure 2.1. It includes three memory stores known as sensory memory, working memory, and long-term memory. Sweller (2005) defines sensory memory as the cognitive structure that permits us to perceive new information, working memory as the cognitive structure in which we consciously process information, and long-term memory as the cognitive structure that stores our knowledge base.

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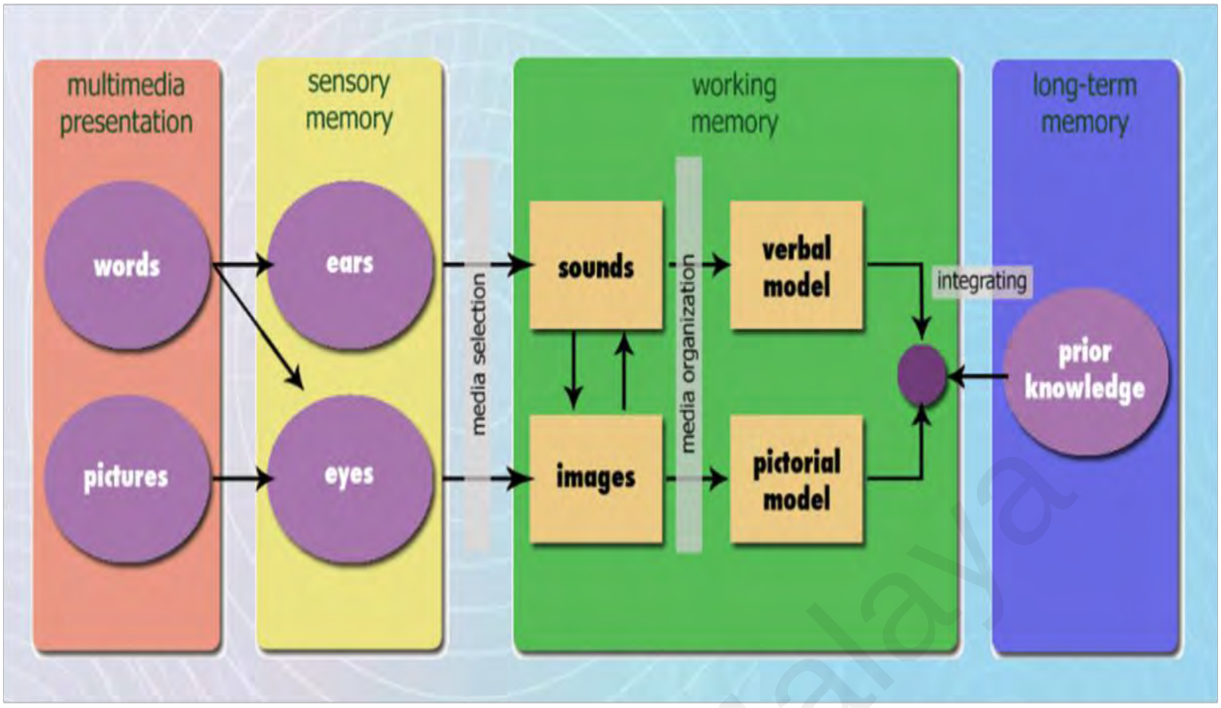

Figure 2.1 : Multimedia Learning Theory

In the late 1990's, the pioneer studies of teaching using multimedia outlined three processes and five principles that the students should be dealing with when adapting multimedia as their learning tools. In particular, when a learner engages in five cognitive processes, he or she involves in the multimedia environment.

Mayer's work started in the late 1990s whereby he outlines three processes when a learner is using multimedia as his or her learning tools. These processes are selecting, organizing and integrating information based upon prior knowledge. In particular, Mayer elaborates that while these processes take place, the cognitive activities are:

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i. selecting relevant words for processing in verbal working memory

ii. selecting relevant images for processing in visual working memory

iii. organizing selected words into a verbal model

iv. organizing selected images into a pictorial model

v. integrating the verbal and pictorial representations with each other and with prior knowledge.

Five principles that should be incorporated by instructors, teachers or developers who are considering to use multimedia as learning tools are:-

i. Multiple Representation Principle: It is better to present an explanation in words and pictures than solely in words that may provide big impact to students. This first principle follows the connections between the major elements in multimedia, which is verbal and visual that may provide a big impact to students

ii. Contiguity Principle: When giving a multimedia explanation, present corresponding words and pictures contiguously rather than separately. The second principle emphasized more on the collaboration between the major elements in multimedia to initiate a simultaneous effect, which may improve student's comprehension. This multimedia cognitive theory provides a conducive atmosphere to that allow student to think creatively (Mayer, 1999).

iii. Split Attention Principle: When giving a multimedia explanation, present words as auditory narration rather than as visual on-screen text. Whereas the

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third principle is more inclined towards how different information are processed for major elements of multimedia and both will act as a platform in helping to understand lesson. This process happened continuously within the students themselves (Mayer, 1999).

iv. Individual Differences Principle: The foregoing principles are more important for low knowledge than high knowledge learners, and for high-spatial rather than low-spatial learners.The fourth principle of the multimedia cognitive theory is more effective to individual with more knowledge in the subject presented, whereas, students without prior knowledge in the subject will be more affected by the elements of multimedia itself.

vi. Coherence Principle: When giving a multimedia explanation, use few rather than many extraneous words and pictures. The fifth principle focused more on students following their learning via multimedia where a more optimised effect is generated in how the adapted information presented more efficiently.

These processes and principles are the factors that established multimedia to the level that can be recognized as a tool that undoubtfully helps students. Multimedia technology's advancement in this era has greatly benefitted all kind of industries.

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2.5.3 THE 2D ANIMATION

A 2D-animation is the creation of moving pictures in a two-dimensional environment. This is done by the order of consecutive images, or "frames", that simulate motion by each image showing the next in a gradual developmental steps. 2D animation used the length and width dimensions in a flat surface, so there are only length and width dimensions without any thickness. 2D surface can be described with the X and Y axes to be able to perform perfectly; the image will be shown with this technique should have a value of x and y coordinates of a minimum of 0 and a maximum resolution used.

There are two types of common 2D animation:

i) Cell Animation

Cell animation is derived from the word "celluloid", which is the basic ingredient in the manufacture of this type of animation as the early years of animation. Cell animation is sheets of animations that form a single animation, each cell is a separate section as an animated object. For example, there are three pieces of cell animation, first cell animation contains the main character, second cell animation contains other characters, and the last one contains background of the animation. All three cell animations will be arranged in rows, so that when the animations is run, they will look like a single unit. Naming a few, examples of this type of animation are cartoons such as Tom and Jerry, Mickey Mouse and Detective Conan.

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ii) Path Animation

Path Animation is the animation of the object movement trajectory that follows the story line that has been determined. An example of this type of animation is an animated train moving in the rail track. It is performed by looping animation where animation continues to repeat until it reaches a certain condition. In Macromedia Flash, when an animation is obtained with this technique, it uses a separate layer defined as object motion trajectory.

2.5.4 2D INTERACTIVE

2D Interactive is commonly related to 2D animation focuses on creating characters, storyboards, and backgrounds in two-dimensional environments. Often thought of as traditional animation, the figures can move up and down, left, and right. They do not appear to move toward or away from the viewer, as they would in 3D animation. 2D animation uses bitmap and vector graphics to create and edit the animated images and its interactivity is created using computers and software programs, such as Adobe Photoshop, Flash, After Effects, and Encore.

2.5.5 3D ANIMATION

3D animation represents the thickness dimensions on the image that makes images much more real than the two-dimensional image. Usually the three-dimensional field is expressed with X, Y and Z axis. As a result of the processing and delivery of light effects to 2D graphics, it becomes a three-dimensional geometric data. 3D animation is

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an animation created using a model such as that derived from wax, clay, puppet / marionette and using the camera to record the animation frame by frame. When the images are projected sequentially and quickly, wax or clay puppet or marionette would seemingly alive and moving. 3D animation can also be made using a computer using software. 3D animation itself is a model that has the shape, volume and space that can be seen from all directions.

2.5.6 3D LEARNING

The advancement of technology especially in the last decade, has witnessed the prevalence of technology into the classroom. Quite recently, efforts have been mushrooming among scholars to study the effectiveness of educational technology in the classroom, pertaining to the student's attainment. Extensive studies have been conducted to document the potential of 3D as learning aids, and these efforts have been extended to dyslexic children (Su & Cheng, 2013).

Exemplifying such work is a study done by Wu and Chiang (2013). They used a realistic 3D research in this era of computer graphic technology and the result is very encouraging. The study aims to increase understanding of the objects in the course of charts orthography This empirical study involved one hundred and twenty Taiwanese freshmen who were asked about four types of visualization, which includes two 2D static depictions (2DT, 2DR), and two 3D animations (3DT, 3DR), to meet five surface styles on orthographic views. The findings demonstrated that applying the 3D animations shows better performance in understanding the appearances and features of objects constructed by oblique and double-curved surfaces. The application of 3D

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animations results also demonstrated a better visual comprehension for students, especially when objects are constructed by the complicated features.

The capability of the 3D graphic axis in simplifying thus helping to improve students understanding compared to 2D axis technique is profoundly undeniable. The student's visual capability proved that 3D axis graphic technology can improve their focus.

Another important aspect, which raised concern among consumers, is the cost of developing a 3D-assisted learning tools. However, it is found that cost is not an issue because 3D design and visual tools such as Google Sketchup and ARToolkit is very competitive in price and that the benefits are far more important. In facing the challenges of today's education, technology and education is inseparable, and the interconnectedness is much needed to create a more effective learning environment.

Even though 2D is still relevant in presenting object which does not need additional interpretation as in 3D (Korakakis et al., 2012), findings from previous studies suggested that the 3D axis graphic technology with animation have better impact in assisting visualisation (Brenton et al., 2007; Frohberg, Göth, and Schwabe, 2009; Bouta, Retalis, and Paraskeva, 2012). Exemplifying this claim is the work by Bouta et al. (2012) who already adapted these techniques in the late 70's era to ensure a more effective learning process using 3D technology. Hence, the capacity of 3D-assisted technology to be adapted in the learning process is very promising.

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Another unique criteria of 3D is the spatial ability that it offers to understand and remember spatial relations among objects. Spatial ability is inheritance ability within student, the only difference is whether the level is low or high. This ability can be viewed as a unique type of intelligence distinguishable from other forms of intelligence, such as verbal ability, reasoning ability, and memory skills. Spatial ability is not a monolithic and static trait, but made up of numerous subskills, which are interrelated among each other and develop throughout our life. Evidence from research suggested that the 3D graphic has helped support the learning process of student with high spatial ability (Brenton et al. 2007; Frohberg, Göth, & Schwabe 2009; Bouta, Retalis, & Paraskeva, 2012; Korakakis et al., 2012). Students with high spatial ability needs lower cognitive ability to translate the 3D model. On the other hand, those with lower spatial ability will need to use more cognitive ability.

This matter is related to dyslexic children (Gay, 2001) who sometimes have a higher spatial ability than ordinary children. The fact has been established in the 1980s (Link, 2000) that dyslexic children possessed a spatial ability with inclinations towards professions such as architecture and engineering. He also emphasized that the children's spatial ability will be more proven in graphic computers job. So, it is relevant to combine dyslexic children' spatial ability with 3D graphic technology.

The technological advances of devices such as iPad and iPhone in this century have created flexibility in operating gadgets which is an important factor in the learning

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process. According to (Sung & Mayer, 2013) further research is needed if more portable devices are to be used due to anticipated bigger impact it may have on the students that will enable them to learn in greater ease.

2.6 ADVANTAGES OF 3D

Discoveries in the computer science field is very dynamic that resulted in drastic transformation. This development demands continuous studies in order to bridge the gaps of knowledge between the content of learning tools and the advancement of technology. One of the profound theory used until today pertaining to multimedia and technology-related studies is the Multimedia Cognitive Theory by Mayer founded in the late 21st century. This theory continues to grow until the last few decades. This theory has become the pillar in the development of multimedia technology as an enabler in a curriculum known nowadays as m-learning (Kearney, Burden, & Rai, 2015).

The potential of using multimedia in learning entails positive impact on children's learning (Furió, González-Gancedo, Juan, Seguí & Rando 2013; Ihmeideh, 2014; Archer et al., 2014).

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The unique interesting characteristics of the multimedia technology which are animation and virtual reality act as motivators that could accelerate the acquisition of learning skill among the children (Wu & Chiang, 2013; Lee & Wong, 2014). This has been assisted by the advantageous elements of 3D such as, “Direction of Rotation”, “virtual environment” and “animation” apart from the basic elements “yaw”, “pitch” and “roll” in basic 3D as shown in Figure 2.2.

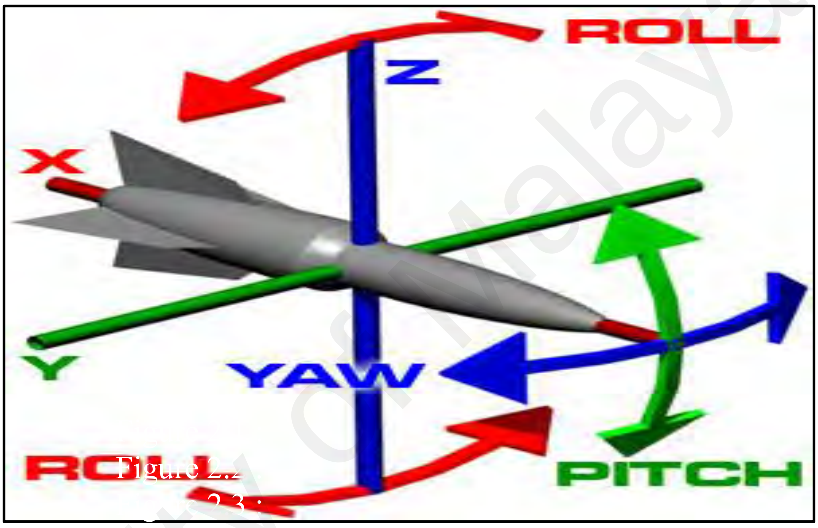

Figure 2.2 : Features of 3D

In the past few years, the world has been witnessing the proliferation of more advanced 3D technologies. These are known as virtual reality (VR) and augmented reality (AR). Both virtual reality (VR) and augmented reality (AR) are artificially computer-generated simulations or recreation of a real life environment or situation that enable an existing reality to be topped up by layers of computer-generated enhancements to make it more meaningful by which users can interact with it, especially in applications for education and entertainment (Kaufmann & Schmalstieg, 2006; Kalyvioti & Mikropoulos, 2014).

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In education, at the beginning of the research, the focus was on the subject of science. Exemplifying the prolific trend of 3D in education is its usage in visualizing the concept of electrochemistry (Talib, Matthews, & Secombe, 2005) which is a very abstract concept that most students suffer. Even though it is not meant to be definitely comprehensive, the visualisation effect embedded in the 3D features help boost students' understanding on the said topic hence their interest in chemistry. This can be a good motivational factor to help promote the participation of students in Science, Technology, Engineering and Mathematics (STEM) fields at the tertiary level. In the same demeanor, the degree of interactivity in a 3D software about animal cells in the subject of Biology field has aided millions of teachers and students in understanding the exquisite anatomy of cells.

To date, making 3D elements as one of the learning media in science and social science is still the focus of ongoing studies. Relating this advancement to the need of the dyslexic children, the 3D effects such as visual, audio, kinesthetic and tactile elements are expected to be multisensory learning stimulus materials that can help boost their learning.

2.7 ANALYSIS ON CURRENT APPLICATION OF 2D AND 3D SOFTWARE

Children of the 21st century are born in a digital world. This inadvertently gives them the opportunity to experience a much more interesting and interactive learning environment. However, those who suffer from neuro-development disorder needed

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much assistance to cope with learning using the digital way. Nevertheless, efforts have been made by many researchers to manipulate the advantages offered by the digital world and cyber space to these children so that they may reap the advantages together with the normal children. Some of the existing teaching and learning tools specifically altered to tailor the needs of dyslexia childeren reviewed were Madrigale, Mylexic, Dyslexia Baca, MathLexic, *Bijak Membaca* and E-Z Dyslexia.

2.7.1 MADRIGALE

Madrigale (Di Tore, Di Tore & Mangione, 2014) focuses on manipulating 2D action video games in his application for dyslexic children between 7 to 9 years old. The application also includes additional exercises such as phonology and spatial-visual. The work shows that extension of 2D objects into 3D objects are possible to benefit the learning process of dyslexic children where interactive capabilities of the 3D itself are able to motivate children with low cognitive but high spatial abilities. Figure 2.3 shows the interface of Madrigale.

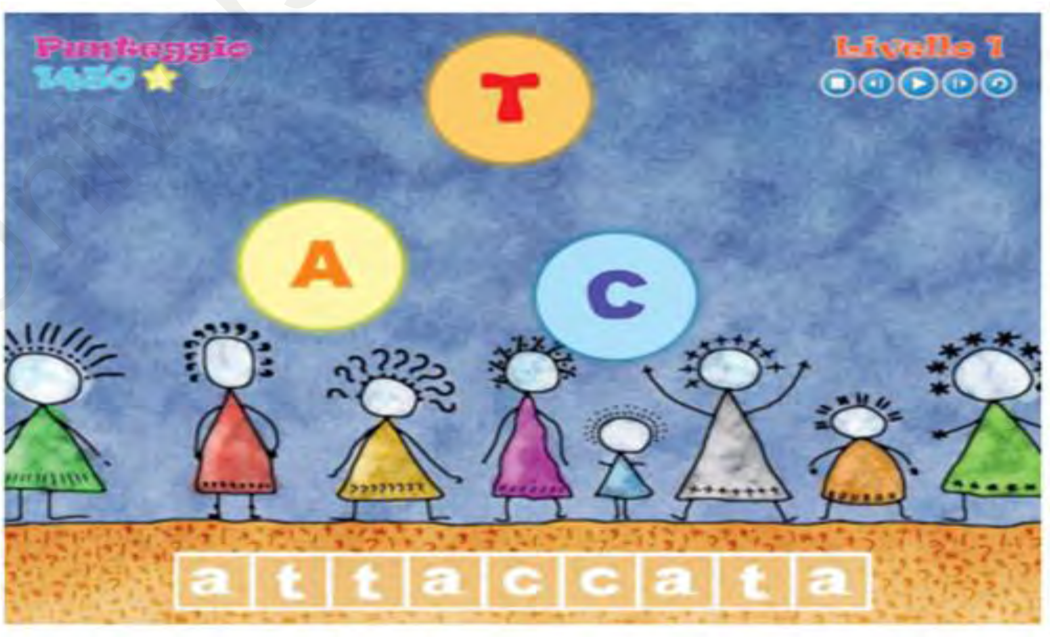

Figure 2.3 : MADRIGALE Interface

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The study of applications using this 'game-based learning' concept combines the design of interaction between education and guidelines in its development. Like the development of other language learning applications, MADRIGALE suppresses the concept of phonology and morphology in learning Italian. The incorporation of characters that constitutes syllable in Italian and one character represents the letters are two different concepts. The same issue was also placed in the development of the application ie by involving children with dyslexia. It is therefore concluded that, there are similarities in difficulties in learning any language be it Bahasa Malaysia or others, due to the romance typeface of letters, type of letters, word length, symbols layout and semantics. MADRIGALE can be used as a guideline and reference to build a prototype in bahasa Malaysia in this present study.

2.7.2 MYLEXIC

The availability of the multimedia technology enhanced with the interactive features make Mylexic application appealing to dyslexic children. Beginning with basic learning stage such as hands movement to shape alphabets to constructing phrases and short sentences, it allows dyslexic children to response directly while using the 2D application. The opportunity for the children to practice hands on learning can be seen while they are connecting dots to form letters as shown in Figure 2.4. This kind of responses will help in developing the children psycho-motor ability. The inclusion of more navigational elements in the form of graphic actually helped to simplify the process for these children to follow through the contents of the application.

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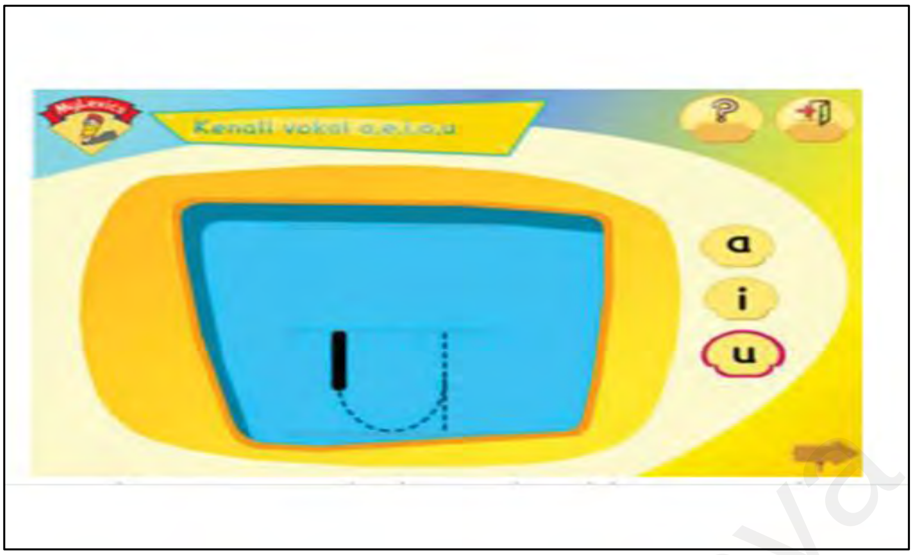

Figure 2.4 : MyLexic Interface

Apart from easing the process of mastering literacy for dyslexic children, the approach and models used in the development phase were also very appealing. The use of the Scaffolding Instructional Technique and Structured Multi-sensory Phonic Teaching theories to form the application framework (Haziq et al., 2009; Izzah et al., 2009.) has created such an environment ideal for this application to reach its targeted objectives.

Using modular approach MyLexic benefits from non-linear learning game. This makes it differ from other courseware in the market. The issue of linearity and non-linearity in a software development is crucial to determine that the content is not boring to users especially for children with learning disability. Hence, the feature contained in Mylexic fulfills the learning criteria needed by these children. Apart from having an interesting interface, the modules can be skipped whenever a child feels bored at a certain stage. This will encourage their prolonged participation rather than forcing them to stay at one singular point when they do not feel like continuing. With these advantages, Mylexic

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has long been used at all centers of Malaysia Dyslexia Association (Persatuan Dyslexia Malaysia) since a decade ago.

2.7.3 DYSLEXIA BACA

The level of concern relating to literacy mastering within school children in Malaysia is growing. A research was successfully done, using Dyslexia Baca application which is highly relevant as a reference for all researches. Dyslexia Baca incorporates many multimedia elements applying the characteristics of development and the elements of multimedia and even discussing its focuses on problematic letters such as p, q, b, d, m and w (Daud & Abas, 2013).

Dyslexia Baca (Figure 2.5) is fully developed using 2D graphic images. The design incorporated in this application is meant to motivate children to identify alphabets. Apart from that an eco-system concept involving three main elements, that is, pedagogy, technology and content are properly adapted in the environment of this application.

The addition of ecosystem concept makes this application interesting to a child who is curious about nature. The children can quickly adapt with the application as they are accustomed to the sense of nature. The next important thing to be learnt through this application is the language learning whereby they will learn the role of living things and

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the death in the ecosystem life. This is the natural experiential learning that the children will undergo.

This application was developed adapting to the Addie model. The above review proposed that the entire development process of Dyslexia-Read is applicable to ThreeDLexic development.

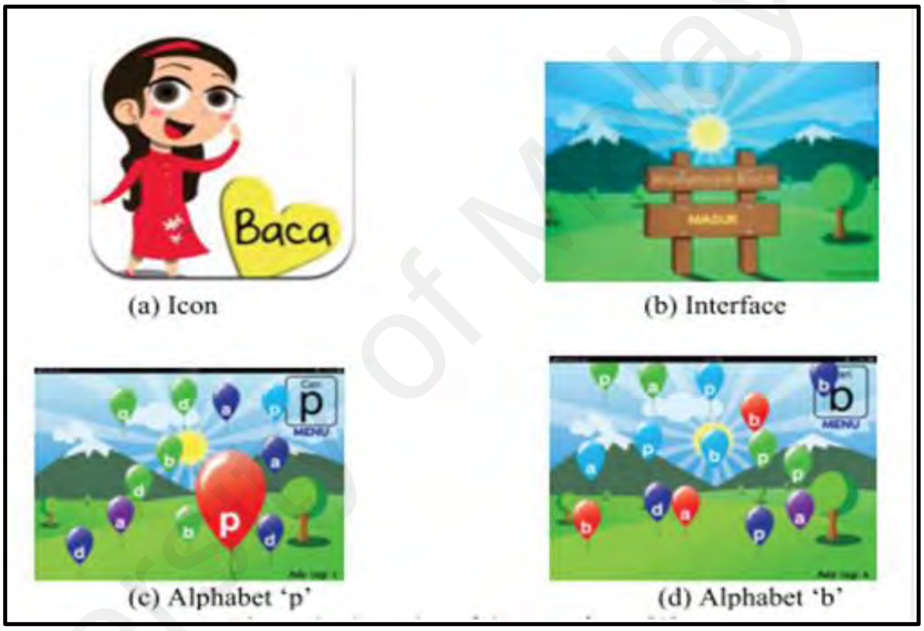

Figure 2.5 : Sample Of Interfaces For Dyslexia Baca

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2.7.4 MATHLEXIC

MathLexic was developed based upon realization that dyslexic children are having difficulties to manage numeracy. Numeracy is one of the most important skills to master in the early stages of Malaysia education system. By integrating the elements of multimedia such as 2D graphics and animations as shown in Figure 2.6, Mathlexic is able to improve the student's learning abilities and proved that this application is helping educators either directly or indirectly (Mara, 2013).

MathLexic was developed using a model that looks like Addie, named as the Usability Engineering Process Model (UEPM). This model involves three key processes: Analysis and Design, Development and Evaluation. Implementation stages in the Addie model are not included in this model. The method used was qualitatively ie analyzing the process using interview and monitoring method. These data are used to create a storyboard before the design process is implemented.

The strengths in the development of this application lies in the presence of a constant (process of obtaining critique of dyslexic children) throughout the development process. From my observation, the data collected from dyslexic children are flexible data because they have the ability to process information. With this, the resulting application can be used by dyslexic children with varying abilities. At the evaluation stage, MathLexic goes through the same process as ThreeDLexic which is evaluated by educators in the field of dyslexia using User Acceptance Test Questionnaires. This process is important to get feedback from the pupils before they reach the end users.

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This process is seen as a mix of two raw materials to reinforce the structure of the application. This process can be emulated when developing the present 3D software so that developers can save time when setting up the applications.

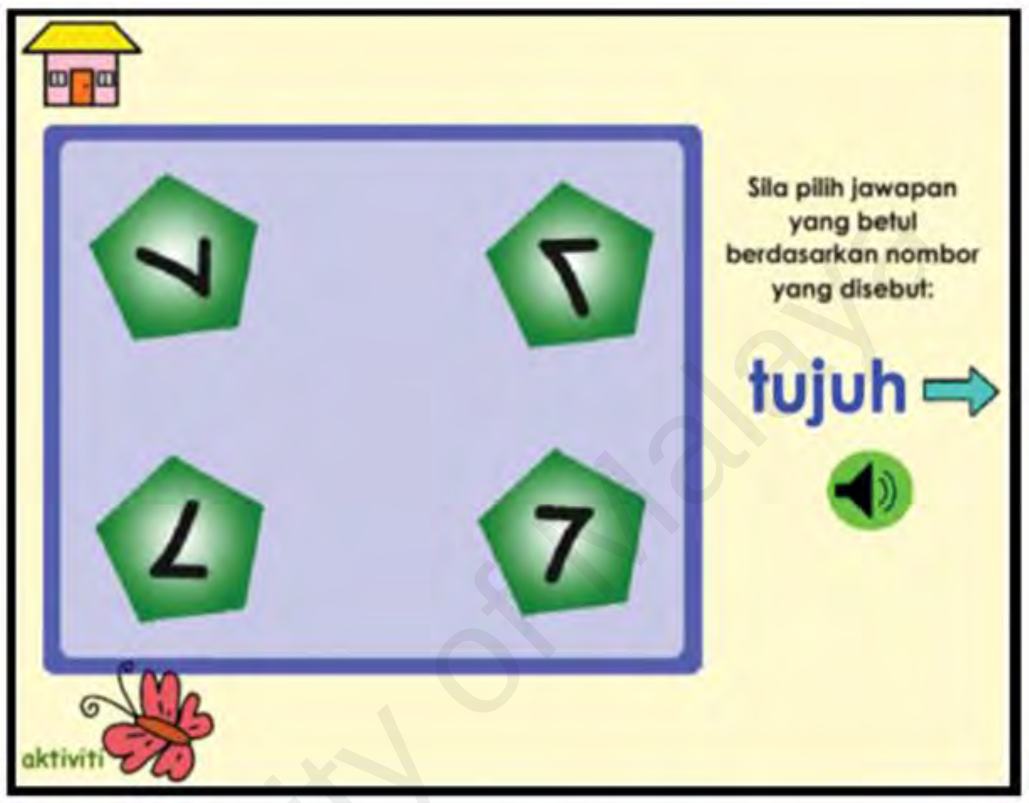

Figure 2.6 : Recognize Activity in MathLexic

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2.7.5 BIJAK MEMBACA

Bijak Membaca takes the approach to improve the phonic pronunciation presented in the form of videos and multi-sensor (Rahman et al., 2012) as shown in Figure 2.7. Although not using the android platform with mobile learning facilities, this courseware is similar to MyLexic. Video is added to re-emphasize the movements of the mouth in uttering the sound of a word. The playback facility can facilitate the children of dyslexia to repeat the sounding cables that represent the letters learned. Using a multi-sensory concept in the module, users of dyslexia are able to visualize the movement of the mouth when pronouncing the letter while listening to the audio carefully and perform the movement of the hand. Heuristic evaluation is used to analyze the effectiveness of multimedia elements in the application.

Figure 2.7 : Letter Sound Using Phonic Reading Technique in *Bijak Membaca*

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2.7.6 E-Z DYSLEXIA COURSEWARE

E-Z Dyslexia Courseware (Manzura & Mahidin, 2014) was developed adhering to two principles; dyslexic should be given more training and dyslexic should follow self-learning. In regard to self-learning, computer technology is made into a bet for these children to overcome the problem of reading and writing. The model used was the Preliminary Courseware Conceptual Model assisted by the Mayer theory, similar to the newly-developed software in this present study. This model incorporates the content, theories and the interface as a whole. The structural engineering between the main contexts of content, theories and interfaces become the strengths and uniqueness of E-Z Dyslexia (Di Tore, Di Tore & Mangione, 2014; Haziq et al., 2009; Daud & Abas, 2013; Siti Zulaiha Ahmad & Noor Izzati Jinon 2013).

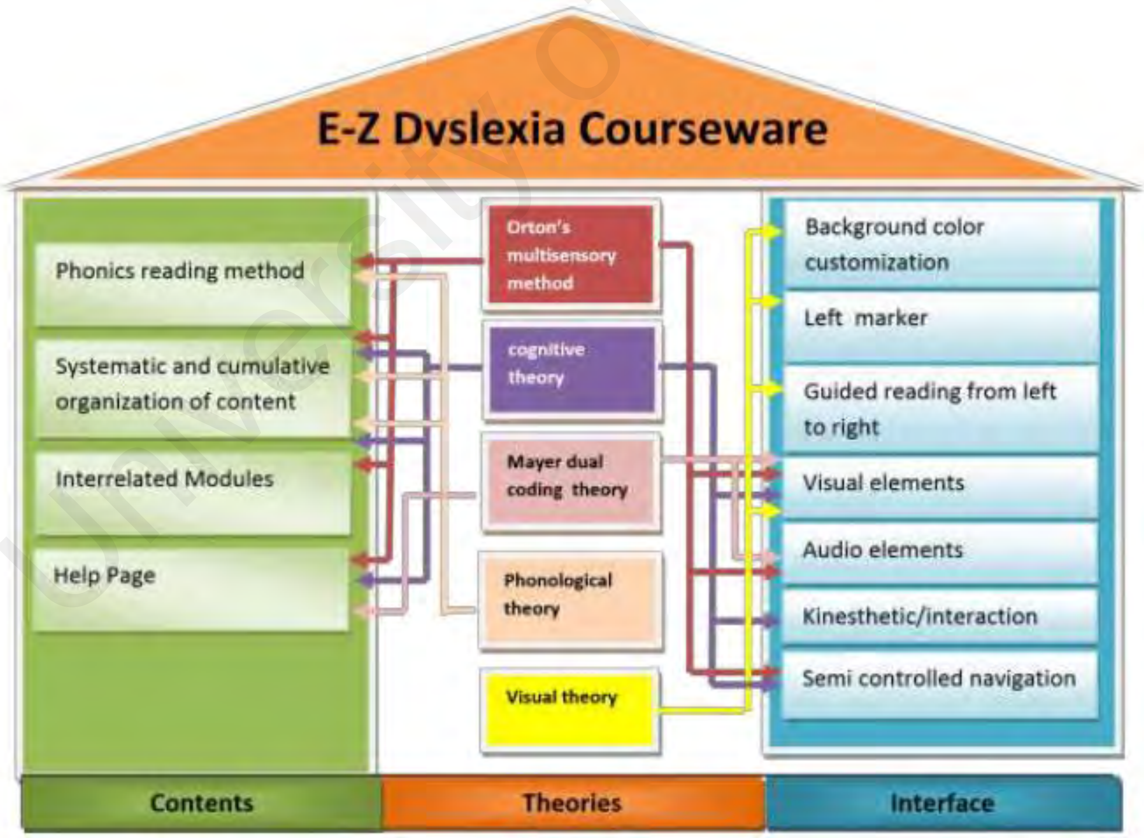

Figure 2.8 : Preliminary Courseware Conceptual Model

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It is a hard process to actually fulfill these criteria in an application. This process is explained in Figure 2.8. It can be a guidance for the next future generation of software development. The lacking aspect of this application is that the visual element has nothing to do with presenting the content. It was just used to make it looks neat. There is an opportunity to replace the visual element with a 3D element if E-Z Dyslexia is about to be updated.

Arguments that language-related applications do not run out of phonological concepts are true. Similarly, based on this awareness, the phonological problem in E-Z Dyslexia is more towards the issues that arise among the children of dyslexia itself. Again the similarities here is to use phonological theory to the phonics reading method.

2.8 INSTRUCTIONAL DESIGNS MODELS

There are various instructional designs (ID) in application development that can be used depending on the objectives of the developers and type of users. The main idea is to use those that could convey something meaningful in a more effective way to end users. The debate in assessing model A or Model B is not relevant as each ID has its own credibility that matches the designer's intention.

For example, the Addie model is only suitable for applications involving implementations. If the intention is to check and view for error during execution, it may

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not be appropriate. Such intention is fulfilled by the Assure model or the Hanafin and Peck model as each phase requires testing.

The next section discusses several models in application development. The discussion is a platform to gauge the suitability of the existing model for this present study.

- Addie Instructional Model
- Assure Instructional Model
- Dick and Carey Instructional Model
- Hanafin and Peck Instructional Model
- Knirk and Gustafson Instructional Model
- Kemp Instructional Model

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2.8.1 ADDIE INSTRUCTIONAL MODEL

The Addie model founded by Rosset in 1987 is one of the models to develop courseware. Its early usage was for military training base. At that time, the revolution in education was also encouraging. There are two studies both done in 2006 to study the effectiveness of the Addie Model. (see the work of Youngmin Lee at Emporia State University in South Korea, 2006 and by Baharuddin Aris, et al's from Universiti Teknologi Malaysia). This study investigated the difference in interest among students in using multimedia with and without Addie model. It is found that majority of the respondents favour the Addie Model.

There are many studies that investigate the characteristics of Addie. The pattern of study can be divided into two: 1) focusing merely on the general feature of Addie, and 2) zooming into investigation on one particular or a couple of specific Addie phases. For example, Arkün (2008) studied the perceptions on the effectiveness of Addie in the early 21st century. In particularly, he suggested that the style of model development can be re-considered by users from its effectiveness. Another focus of study was demonstrated by Welty who had studied the design phase in specific in 2007. As time went by, more interest has been shifted into unburying the characteristics of a single Addie phase. In 2015, Aldoobie investigated the analysis phase while in 2010, Dousay and Logan studied the analysis and evalution phase. Another area of research also evolves around the development for content (Muruganantham, 2015).

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The phenomenon entails that Addie model is favorable by many researchers when it came to developing an application.

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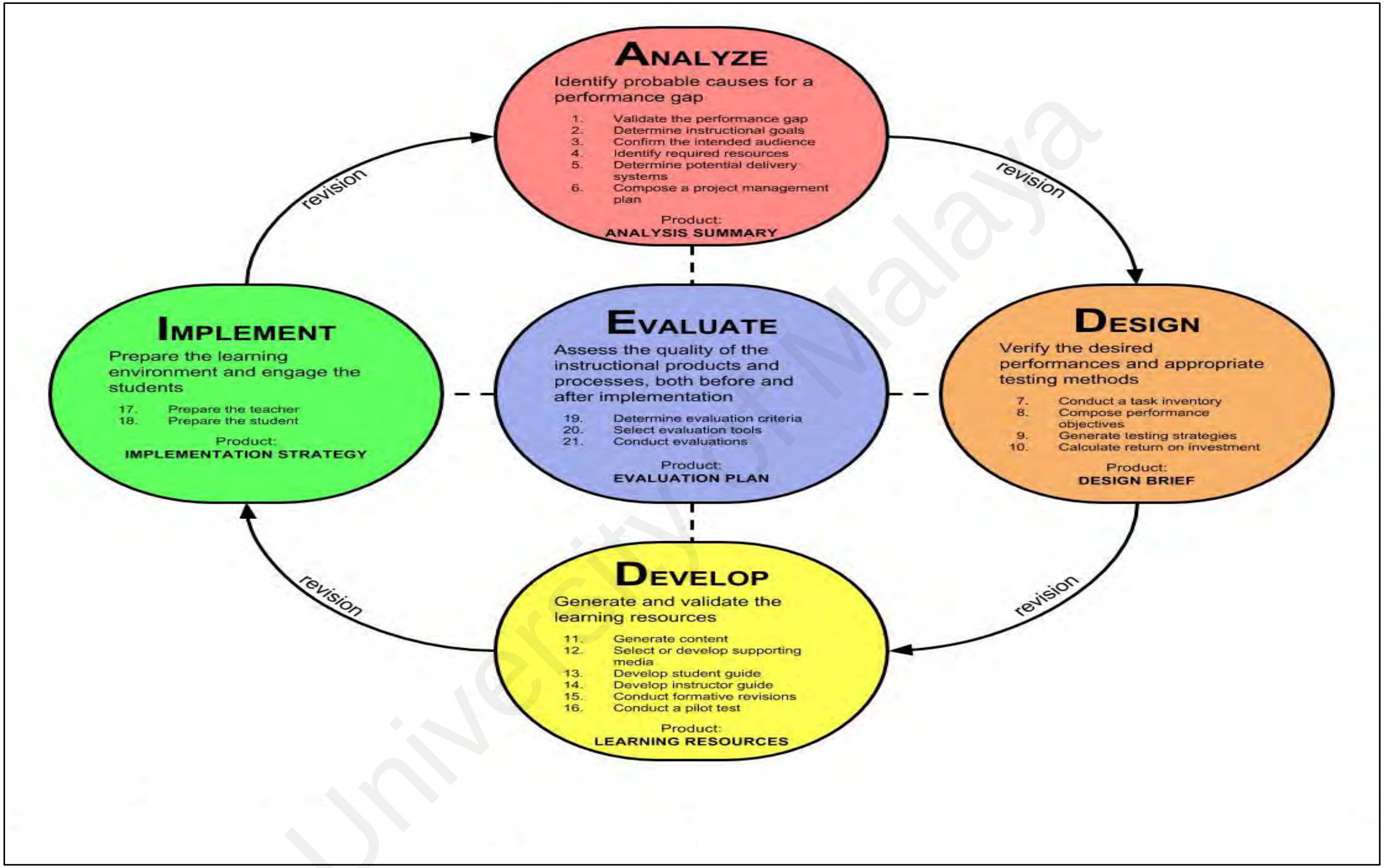

Figure 2.9 : Addie Model

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Addie (Figure 2.9) is divided into five major parts are (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. The use of the model Addie instructional design may be able to increase the attention and motivation of students. This subject will be discussed in details in the methodology chapter.

2.8.2 ASSURE INSTRUCTIONAL MODEL

The ASSURE (Figure 2.10) model is a model of teaching design that can be used to plan the use of media systematically. This model was drafted by Heinich and colleagues in1982. It aims to provide guidelines for planning and conducting teaching using media. Focusing on lesson planning in classroom situations, the ASSURE model is intended to ensure that learning takes place.

There are six steps as symbolized by the acronym of ASSURE that functions as the framework in its implementation: Analysis, State Learning Objectives, Select Methods, Utilise media, Require learner participation dan Evaluation.

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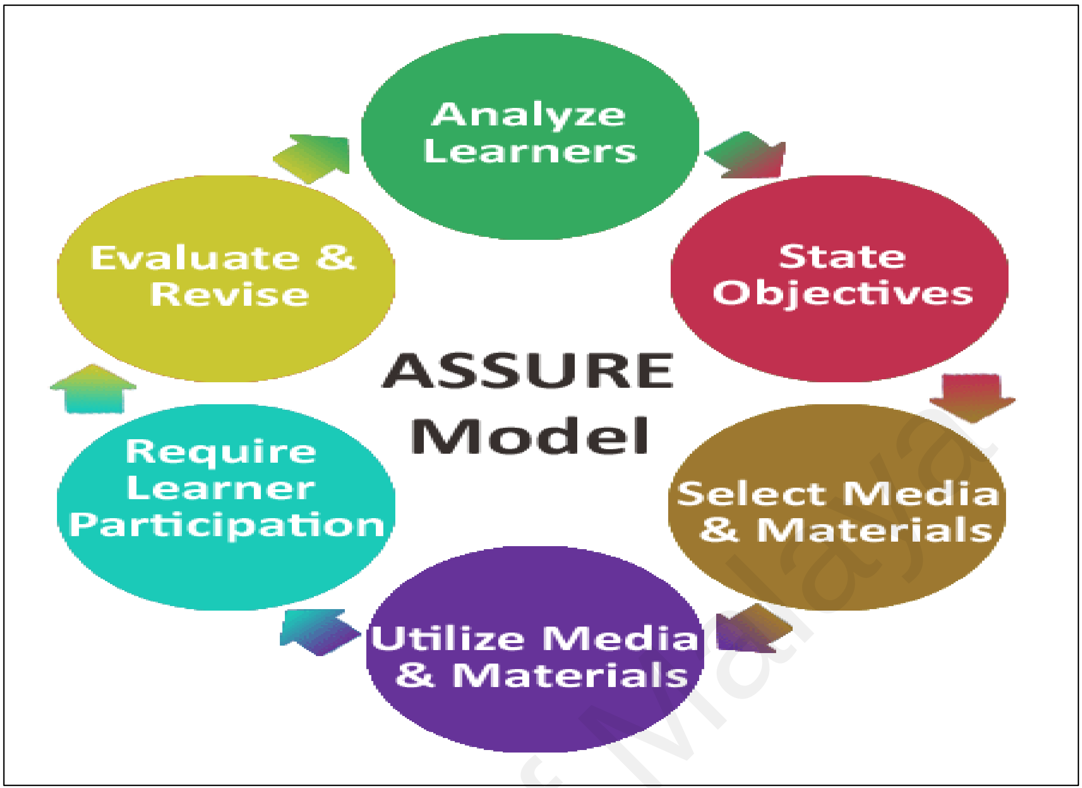

Figure 2.10 : Assure Instructional Model

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2.8.3 DICK AND CAREY INSTRUCTIONAL MODEL

The model was originally published in 1978 by Walter Dick and Lou Carey in their book entitled The Systematic Design of Instruction. The model addresses instruction as an entire system, focusing on the interrelationship between context, content, learning and instruction.

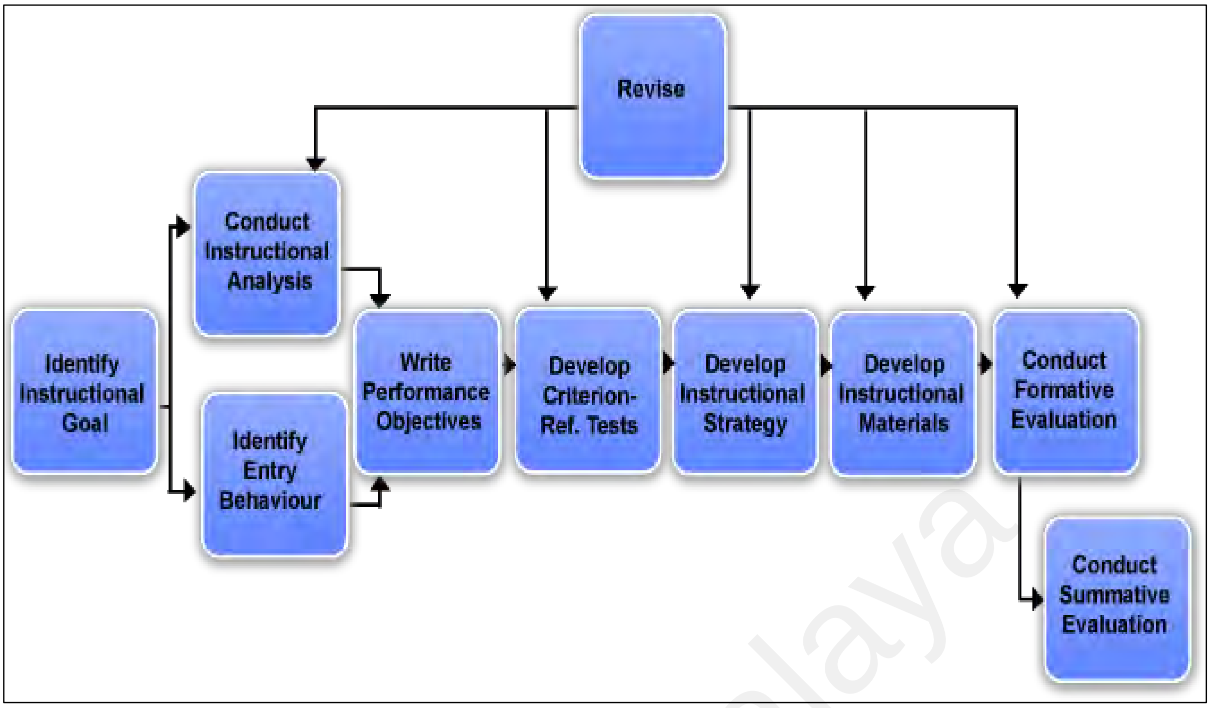

Figure 2.11 : Dick And Carey Instructional Model

From the Figure 2.11, the components of the Dick and Carey Model, also known as Systems Approach Model, are as follows:

- Identify Instructional Goal(s): goal statement describes a skill, knowledge or attitude (SKA) that a learner will be expected to acquire.
- Conduct Instructional Analysis: Identify what a learner must recall and identify what a learner must be able to do to perform particular task.
- Analyze Learners and Contexts: Identify general characteristics of the target audience including prior skills, prior experience, and basic demographics; identify characteristics directly related to the skill to be taught; and perform analysis of the performance and learning settings.
- Write Performance Objectives: Objectives consist of a description of the behavior, the condition and criteria. The component of an objective that describes the criteria that will be used to judge the learner's performance.

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- Develop Assessment Instruments: Purpose of entry behavior testing, purpose of pretesting, purpose of posttesting, purpose of practice items/practice problems
- Develop Instructional Strategy: Pre-instructional activities, content presentation, Learner participation, assessment
- Develop and Select Instructional Materials
- Design and Conduct Formative Evaluation of Instruction: Designer tries to identify areas of the instructional materials that are in need of improvement.
- Revise Instruction: To identify poor test items and to identify poor instruction
- Design and Conduct Summative Evaluation.

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2.8.4 HANNAFIN AND PECK INSTRUCTIONAL MODEL

The Hannafin Peck (1987) design model (Figure 2.12) is a three-phase process: Needs Assess, Develop or Implement. These three phases require repetition in the assessment. In the first phase, a needs assessment is performed. This phase is followed by a design phase. In the third phase, instruction is developed and implemented. In this model, all of the phases involve a process of evaluation and revision. The Hannafin Peck's design model is simple but pleasing as all the three phases are connected to "evaluate and revise". This is not a model designed for a beginner. It focuses on quality and complexity is appealing.

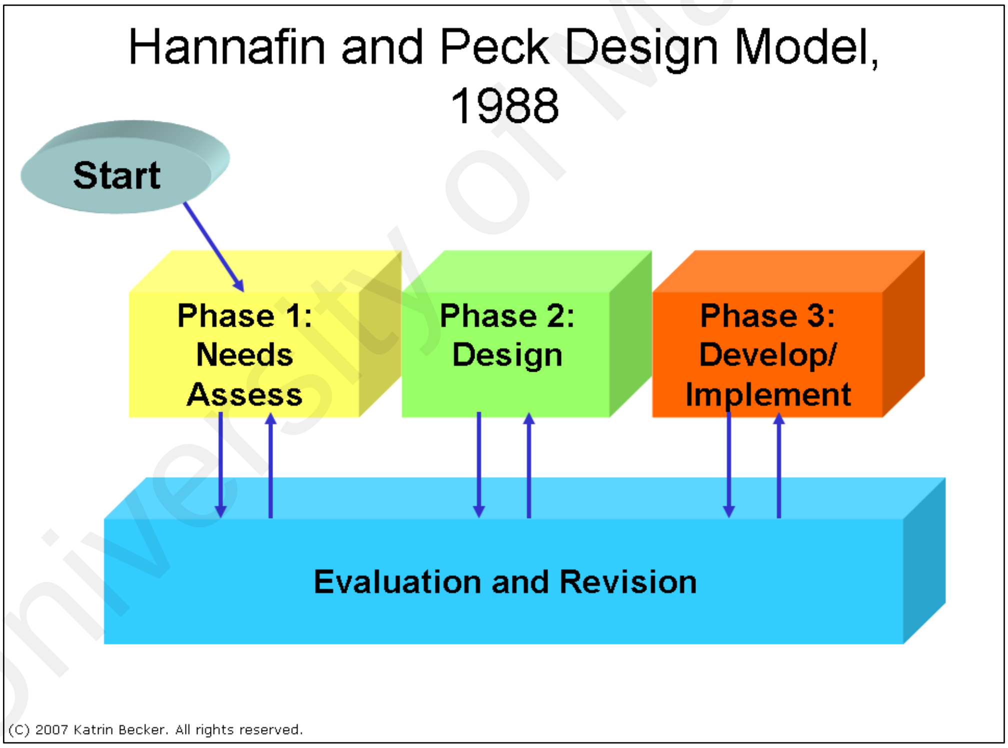

Figure 2.12 : Hanafin & Peck Instructional Model

In detail, there are seven sub-processes during the Needs Assessment phase, Information Collecting Stages, Gap Identification Stages, Performance Analysis, Identifying Constraints and Resources, Identification of Student's Character, Identification of Goals and Final Determining the Problem (Glasgow, in Vienna Sanjaya, 2008: 93). This model is also a product-based and popular model for game application development.

Studies on this model (see Taylor, 2004; Pappas, 2016; Marwan, 2017) support that the three main phases leading to application construction require careful evaluation process and this will ensure that errors can be avoided during the development process. In addition, they agree that this model is able to create an effective and creative learning process. Thus, in sum, the Hanafin & Peck model is a simple and easy-to-use model especially for designers at the beginner level. Only basic knowledge is required and each evaluation phase facilitates the learning for beginners.

2.8.5 KNIRK AND GUSTAFSON INSTRUCTIONAL MODEL

The Knirk & Gustafson Instructional Model is not as popular as Addie and ASSURE. The model was introduced in 1986 by Knirk and Gustafson. Like other instructional models, it basically contains three main phases namely analysis, design and evaluation. Taylor (2004) in his study on this model agree that this model puts the emphasis on problem determination before embarking on the design and development. Noticeably, the phases that served as main phases in Addie and ASSURE are used as sub-phase in Knirk & Gustafson model.

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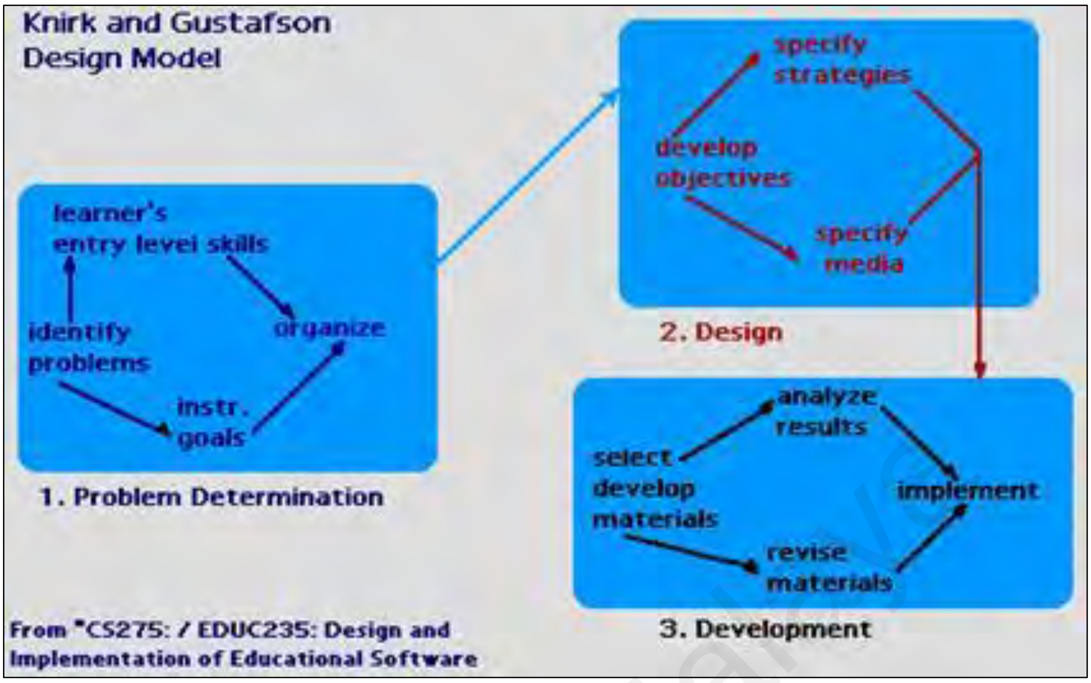

Figure 2.13 : Knirk & Gustafson Instructional Model

From Figure 2.13 above, the content of the model are as follows:

i) The problem determination stage includes identification of the problem, definition of the pedagogical goals and identification of what the learners can do (knowledge, skills, learning styles, affect, etc.).

ii) The design stage includes developing objectives and specifying strategies.

iii) The development stage includes development of materials, testing and revision.

2.8.6 KEMP INSTRUCTIONAL MODEL

This model emphasizes the interdependencies of each step in the process, highlights the importance of the evaluation, and recognizes more environmental factors in an educational setting, i.e. the resources and the support (budget, facilities, time, equipment, personnel and materials).

The characteristics of the model:

i) A general systems view of development: all elements are interdependent
ii) All the elements can be performed simultaneously
iii) Developer can start anywhere
iv) Learning needs, goals, priorities and constraints determine the instructional solutions.

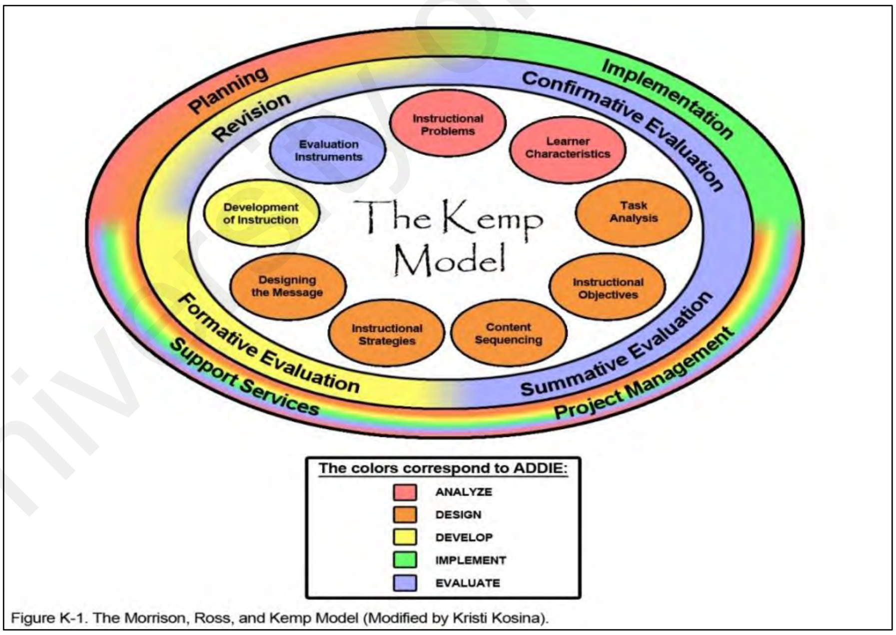

Figure 2.14 : The Kemp Model

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Figure 2.14 depicts nine Elements of the Kemp Model which are represented by the bubbles in the inner section. These elements are derived from Gustafson and Branch's (2002) *Survey of Instructional Design Models*.

i. Identify instructional problems and specify goals for designing an instructional program.
ii. Examine learner characteristics that will influence your instructional decisions.
iii. Identify subject content and analyze task components related to stated goals and purposes.
iv. Specify the instructional objectives.
v. Sequence content within each instructional unit for logical learning.
vi. Design instructional strategies so that each learner can master the objectives.
vii. Plan the instructional message and develop the instructions.
viii. Develop evaluation instruments to assess objectives.
ix. Select resources to support instruction and learning activities.

This model generally requires extensive experience in building learning content. This is because each phase requires deep research. Naturally, there is no starting point for those who used this model. However, repeated work arrangements will cause boredom if this model is not deeply mastered..

Based on the above literature review, a table was created to justify the selection of Addie as the ID model for ThreeDLexic development. The next description and discussion are based on the table below. It should be emphasized here that each model

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has its strengths and weaknesses. However, the choice of Addie ID is based on background of researcher knowledge in both areas, namely knowledge related to application development and knowledge on subjects of study ie dyslexic children. These two different fields are actually the strengths to generate a prototype application. According to Gustafson and Branch (1997) when an educator wants to decide on the appropriate model selection, there are nine characteristics involved. This guideline is based on references from numerous studies which consider the reliability and validity aspects of a prototype. In the word of Tan (2005):

> "Each model offered valuable benefits and guidance applicable to the instructional design process depending upon the institution's needs, purpose and setting. The characteristics and design for each model were compared and contrasted. Several similarities and differences were found during the analysis".

The table shows the criteria justification for selecting Addie based on Gustafson and Branch (1997) taxonomy. The models compared are Addie, ASSURE, Knirk and Gustafson, Kemp, Dick and Carey and Hannafin and Peck. This comparison aims to facilitate the selection of the model to be used in an instructional development based on ThreeDLexic development needs. At first it was difficult to make choices against existing IDs. However, after viewing the requirements in the ThreeDLexic development phase and mapped it on the nine criteria of Gustafson and Branch (2002b), it was found that Addie met all the requirements. The nine criteria are: -

- Resources committed to the development effort
- Whether it is a team or individual effort
- ID skill and experience of the individual or team

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- Whether most instructional materials will be selected from existing resources or represent original design and production
- Amount of preliminary (front-end) analysis conducted
- Anticipated technological complexity of the learning environment
- Amount of tryout and revision conducted, and
- Amount of dissemination and follow-up occurring after development

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Table 2.5 : ThreeDLexic Justification Instructional Model Using Gustafson and Branch (1997) Taxonomy

Number	Instructional Model (ID)	Model Orientation	ThreeDLexic Criteria Justification								
			Typical Output	Resources Committed to Develop	Team or Individual Effort	ID Skill/Experience	Emphasis On Development or Selection	Amount of Front-End Analysis/ Needs Assessment	Technological Complexity of Delivery Media	Amout of Tryout and Revision	Amount of Distribution Dissemination
1	**Addie**	Product	Self instructional or instructor delivered package	High	Usually a team	High	Develop	Low to medium	Medium to high	Very high	High
2	**Hannafin and Peck**										
3	**Knirk and Gustafson**										
4	**ASSURE**	Classroom	One or a few hours of instruction	Very low	Individual	Low	Select	Low	Low	Low to medium	None
5	**Kemp**										
6	**Dick and Carey**	System	Course or entire curriculum	very low	Team	High/very high	Develop	Very high	Medium to high	Medium to high	Medium to high

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Initially, many ID meet the needs of ThreeDLexic. Knowledge in the field of multimedia technology is also related to operating system operating platforms like iOS or Android. The first requirement is to whom the ThreeDLexic target is intended. Because there are IDs based on orientation, abortion such as ASSURE, Kemp and Dick and Carey which are not the right choice although these three models have three main bases of Analysis, Design and Evaluation that are linear and dynamic. The ASSURE model has actually been the first choice when comparing with the phases found in other models. However, through a field study, it is found that this model is classroom-oriented, which is equivalent to Kemp's model. Whereas, ThreeDLexic requires a product-oriented model. Both have a less appropriate clock cycle process in the development of the ThreeDLexic prototype because the design and development process takes a long time if there is an error during the implementation of the evaluation phase. After all, ThreeDLexic development only requires a model that runs linearly. These circumstances will be problematic because the experts who will be involved in the evaluation phase need to repeatedly do so. While this phase only requires one-time implementation.

Based on Table 2.5, only three options are available: Addie, Hannafin and Peck models and Knirk and Gustafson. These three models are product oriented. The intended product is an application that uses multimedia technology. In addition, the phases found in the Hannafin and Peck models used for the development of the EZy Mirror Braille (Marwan, 2017) require the phases that need to be repeated many times during the evaluation. As opposed to this need, the development of ThreeDLexic requires linear route or process only. Some comparisons were made based on previous studies (Knirk & Model, 1986; Gustafson & Branch, 2002; Taylor, 2004;(Tan, 2005). The Knirk and

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Gustafson Model also have great weakness, and the stages are in a sequence but not cross-related. Addie Design model does not only have evaluation and revision in each stage, it also uses them to relate one process to another. So the components of each process are joint together to achieve the instructor's goal.

2.9 MULTIMEDIA TECHNOLOGY IN LEARNING

The multimedia technology is able to aid everybody including children with learning difficulties (Kearney, Burden & Rai, 2015). The characteristics of the multimedia technology such as animation and virtual reality integration have become motivating factors for children to master literacy in a shorter period (Furió, González-Gancedo, Juan, Seguí, & Costa, 2013). Hoffler and Leutner (2011) in their work stressed that 3D applications may stimulate learning environment for students with learning difficulties. In European countries, the technology was already used to help children suffering from learning disorder.

Related researches carried out in the 1990s established that the effectiveness in applying the virtual reality learning environment seems more harmony and contributed to the prosperity of a nation. A holistic study is needed to ensure that the virtual reality environment is properly absorbed into the psychology of each and every students (Lee, Hsiao & Ho, 2014). Various angles needed to be carefully studied before actually adapting an environmental friendly virtual reality (Lee, Hsiao & Ho, 2014). A new mechanism should be created to ensure that the simulation actually contributed to the effectiveness of the learning process (E. A.-L. Lee & Wong, 2014).

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This issue was noticed as early as in year 2000. But a few restraining factors still exist in the process of achieving a standard in consolidating resources and financial (Archer et al., 2014). The positive effect of the technology itself should be integrated with other elements in the learning process so as to achieve greater outcome. The evolution of the growth of multimedia already reached a level that may provide optimum contribution to the learning process. Moreover, this positive development may increase the motivation within the children through their learning process (Furió, González-Gancedo, Juan, Seguí, & Costa, 2013).

This concept of using multimedia as a learning tool continue to grow until the 21st century, leading research into the other multimedia technology advances, m-learning (Kearney, Burden & Rai, 2015) which become a tradition in the learning process. This is because this positive development provided an impact to the children in mastering literacy (Archer et al., 2014).

2.10 ASSISTIVE TECHNOLOGY

During the past few years, children as young as three year olds have been exposed to the computer technology environment whether as their learning or entertainment tools(Toki, Drosos, & Simitzi, 1990). Teachers and students are equipped with sophisticated tools to ease their teaching and learning. Information is only at finger tip. Two decades ago nobody thought that it was possible for technological advancement to lead the creation of devices as big as human palm or the size of an A4 paper in providing mobile learning (m-learning) with no barrier in getting new information.

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Work done by Gotesman and Goldfus (2009) established that assistive technology is very helpful in achieving the learning objectives for children with difficulty in reading specifically dyslexic children. The two types of assistive technologies are (1) facility provided in communication devices and (2) facility which utilise Internet site. The prior may include program such as text to speech, speech to text and proof-reading, which are very useful to help in decoding, reading comprehension, handwriting, directionality, expressing and, encoding. Table 2.6 describes more specific needs required associated with the technology.

Table 2.6 : Matching AT to Students' Specific Needs Assistive Technology

Specific Need	**Assistive Technology Decoding**
Decoding (sounding out words) Reading comprehension	Text-to-speech programs
Handwriting Directionality Expressing	Speech-to-text programs
Expressing words in written form	Word processors Word prediction programs
Encoding (spelling)	Proofreading programs Spell checkers
Organization	Outlining/brainstorming programs

Table 2.6 shows the facility, which utilises internet site as one of the assistive technology medium. Types of difficulties faced by dyslexic children are reading, writing, planning and organization, spelling and word prediction. Adapted assistive to consider are ReadPlease, NauralReader, TextAloud, TextAssist, Kurzweil, DragonNaturally Speaking Intelitalk, Inspiration, WordQ and PredictorPro. All online software can be downloaded through the available Internet site.

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Table 2.7 : AT According To Types of Difficulty/Impairment Type

Type Of Difficulty	At To Consider	Internet Site
Reading	ReadPlease Natural Reader TextAloud TextAssist Kurtzweil	www.readplease.com www.naturalreader.com www.textaloud.com www.textassist.com http://www.kurzweiledu.com
Writing	DragonNaturally Speaking Intellitalk	http://www.nuance.com/naturalSpeaking http://www.intellitools.com
Planning and Organization	Inspiration	http://www.inspiration.com
Spelling and Word Prediction	WordQ Predictor Pro	http://www.wordq.com http://www.readingmadeez.com/products/PredictorPro.html http://www.wordq.com

2.11 USING UNITY AS AN APPLICATION EDITOR

Unity is a fully integrated development engine that provides easy functionality to create games and other interactive 3D content. Unity can be used to assemble art and assets into scenes and environments; add lighting, audio, special effects, physics and animation; play test while editing the application and the application can be run on various platforms, such as Mac, PC and Linux desktop computers, iOS, Android, Windows Phone 8, Blackberry 10, Wii U, PS3 and Xbox 360. , (Villacis et al., 2014), (Wang et al., 2010),(Chiou, Tien, & Lee 2015) and (Dolphin, 2009) concurred that the use of game engine Unity3 as an editor to develop application in their researches is very relevant.

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With the availability of virtual reality technology, the prospect of creating a more advanced application in fact resulted in an interface that seems real and lifelike in an application. The capability of the Unity 3D image is highly in making digital games more appealing. This is supported through its 3D environment, multiplatform suitability and programming language as briefly described below.

2.12 3D ENVIRONMENT

The 3D environment in Unity 3D is the main factor in performing editing. Its modern 3D technology is able to inspire cognitive learning and add logical value in learning activity (Villacis et al., 2014). In giving priority to the psycho-motor activity needed by the children, relevant 3D environment should be used in tandem with learning environment.

Research conducted by Villacis et al., (2014) gave priority to the cognitive development for children. Intelligent agents, modern 3D technology approaches such as Unity 3D Game Engine and Photon Cloud are used to accomplish the cognitive development environment.

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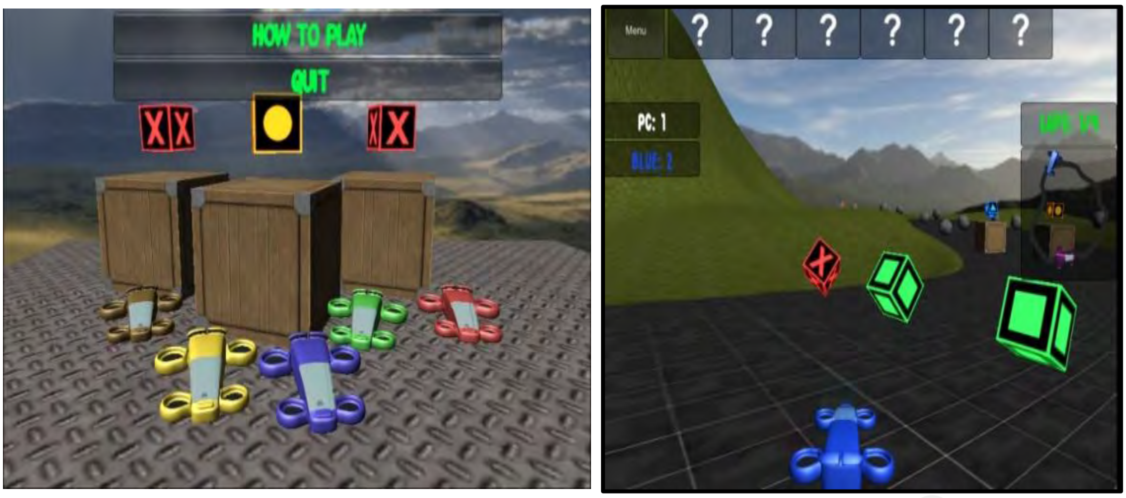

Figure 2.15 : Pictures in which Geometric Figures, Road Map Trace Menu Botton, Colors, Cubes, Obstacles, etc are demonstrated

2.13 PIAGET'S LEARNING THEORY

In this research, Piaget's learning theory was also used. He initiated the concept of a schema, with the basic psychological drive that has the subject media interaction with the world (Villacis et al., 2014). This is to make the different schemes interact in various fields. The variety of schemes includes cognitive, perceptive, motor and affective ones. As a result, the 3D environment generated by Unity is in harmony with Piaget's learning theory.

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2.14 THE SUITABILITY OF MULTI PLATFORM

Platform is an important factor in making it easier for end users to access whatever application developed. Unity 3D is a multi platform editor which works on Android, IOS, Windows, and Blackberry (Kim et al., 2014; Law, Lee & Yu, 2010).

Researches by Wang et al. (2010) and Kim et al. (2014) stressed that selecting a correct platform will ensure that all smart-phones functions are utilized. Apart from communicating smart-phone users may also use their smart-phones as a camera which can be adapted to the virtual reality (VR) and augmented reality (AR). These facilities will be a finishing point for students when integrated with real objects in the real world. In their researches a few VR and AR based games was considered in the process of selecting an appropriate platform.

Research by Wang et al. (2010) was more towards the capability of Unity for VR which is able to publish a real situation of a location to an online system. Advantages proven in this research is that the use of a suitable platform may generate an effect such as surface, shadow effect and natural effect. Example can be seen in the table below:

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(a)

(b)

Figure 2.16 : The Results Of Virtual Reality Based on Unity 3D a) Looking at The Building b) From Earth Surface

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2.15 PROGRAMMING LANGUAGE

Programming language is very important in the development process of an application. Unity 3D utilizes several main programming language in its environment (Wang et al., 2010). Because Unity is a game engine editor, users need to master programming language in order to develop any action game object. Programming language is needed to insert and make the game objects walk, run, jump, explode and disappear. Programming language is also needed to navigate from one page to another. Programming language such as C#, VB.net, VB6, Delphi, Java and a few others can be used in the Unity environment.

2.16 CONCLUSIONS

In the process of performing the development of an application, two important factors should be considered. The first factor is related to technical aspect and the second is related to education. As for platforms (e.g Android or standalone), 3-Dimensional and 2- Dimensional technology, curriculum sequencing and problem solving support are the technical elements. The application domain, learner characteristic captured by the learner model and pedagogical framework (teaching, learning theories, approaches) adopted to guide the adaptation are example of educational aspects considered. In more detail, the adopted pedagogical framework that affects application adaptive behavior takes into account several characteristics of the learner and exploits the adopted main model, which is usually defined by the expert-teacher based on his or her teaching experience.

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Based on several application reviewed, the use of multimedia elements in the development of learning application for children is highly beneficial for them. MyLexic and Dyslexia Baca applications possessed near identical characteristics with ThreeDLexic. ThreeDLexic applied 3D approach in constructing letters in its application. Characteristic such as dividing users into three levels that is, Basic, Intermediate and Advance is the same with those applied in MyLexic and Dyslexia Baca. This is a very important factor to its end users, as dyslexic children require learning contents in different levels. Age requirement for 3DLexic and most application is the same, that is, between 6 to 12 years old. Even interface and colour scheme is more or less the same. In the meantime ThreeDLexic's feature of providing rewards and points are not fully utilized. This is because the developed application was only at a prototype stage to study the effectiveness of learning on only the ten alphabets. On the other hand, MyLexic included the whole Bahasa Malaysia syllable in its application. More information on ThreeDLexic will be discussed in the next chapter.

Table 2.8 : Characteristics of Available Applications

Characteristic	**Application**					
	Madrigale	**Mylexic-2D**	**Dyslexia Baca**	**MathLexic**	**Bijak Membaca**	**E-Z Dyslexia**
Platform Android	No	No	No	No	No	No
Level Of Difficulty	No	Yes	No	No	No	Yes
3D Technology	No	No	No	No	No	No
3D Rotation	No	No	No	No	No	No
Color Scheme	No	Yes	No	No	No	Yes
Bahasa Malaysia Language	No	Yes	Yes	No	Yes	Yes

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From the review, it further motivated me to use the 3D technology as the core element to be integrated in the developed software. Most of the applications discovered previously used 2-dimensional compared to 3-dimensional techniques. Since, the end users are dyslexic children who suffer from learning difficulties, a new approach is needed to ensure a much more effective learning environment for this children.

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CHAPTER 3

RESEARCH METHODOLOGY

3.1 OVERVIEW

This chapter discusses the research design adapted by the study and the methods involved to collect and analyse the data. In particular, it elaborates on the development and implementation using the Addie Model. The discussion for the data collection is embedded in the elaboration of the Addie phase. The prototype that was tested to the experts, teachers and the children during implementation phase is also presented. Their opinions were gathered and subjected to Fuzzy Delphi Method for analysis. This chapter concludes with a summary of the research navigation.

3.2 THE RESEARCH DESIGN

The design of the research is mixed methods (Johnson & Onwuegbuzie, 2004) in nature. It is carried out using both qualitative and quantitative approaches (refer to table 3.1 below). As one of the research objectives is to understand how dyslexic children recognized specific alphabets that deemed to be problematic as proposed in the literature, their behavior was observed while using the prototype. The opinions of 10 domain experts and teachers were also sought in order to capture their agreements and disagreements with regards to the features of the prototype. Due to its pragmatic intention, the research design aligns with the tenets of Addie model in designing the

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Instrumen Saringan Dyslexia (Dyslexia Screening Instrument) as explained in Chapter 2. The following Figure 3.1 illustrates the navigation flow of the research.

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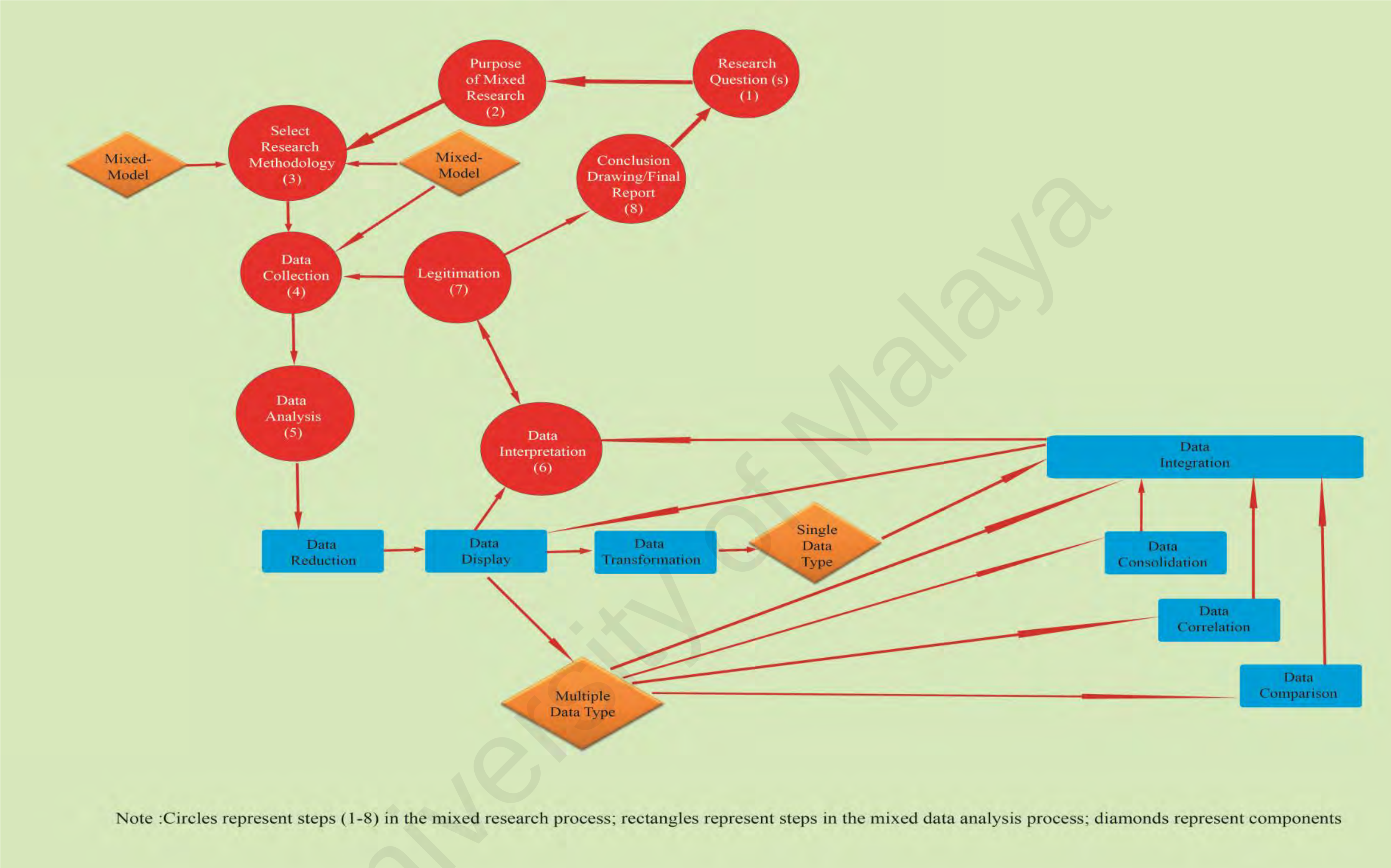

Figure 3.1 : Mixed Research Process Model (Adapted From Johnson & Onwuegbuzie, 2004)

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The above figure depicts the model (Johnson & Onwuegbuzie, 2004) that was adapted in this study. The first step involves three research questions namely:

i) What are the problematic alphabets particularly the reversal letters demonstrated by dyslexic children in their learning?

ii) To what extent the existing technology-aided intervention has helped improve the reading and writing skill among the dyslexic children in Malaysia, thus far?

iii) To what extent the developed 3D animated assistive-reading software can assist dyslexic children with their difficulty to correctly identify the reversal letters?

Referring to the third objective ie to develop a prototype, a model of ISD (Instrumen Saringan Dyslexia) needed to be chosen. As mentioned in Chapter 2, Addie was employed due to the rationale already discussed in the chapter. The elaboration on how the Addie model was used in this study is briefly described here and further elaborated in Chapter 4.

Multiple source of data was collected during the fifth step of Addie ie Implementation stage. It involved both observation (qualitative) and questionnaire (quantitative). Data analysis was performed using Atlas.Ti and Fuzzy Delphi Method (FDM) software for both qualitative and quantitative data respectively.

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Steps 6 and 7 require two-way interactions between the process of interpretation and legitimation. This is the strength of this study because the phase of analysis and evaluation are inter-related and require strong data findings. For example, in Chapter 6 there is a detailed description of how to analyse the 5 letters (b, d, m, p and v) to gauge the extent to which the dyslexic children use the ThreeDLexic prototype to write the letters consistently. This relevance involves seven ways how the data is networked to one another.

3.3 MODEL OF PROTOTYPE DEVELOPMENT

To develop software or technology-based training modules, developers used numerous instructional systems design (ISD) models. Exemplifying such models are Addie, Assure, Dick & Carey and Kemp Instructional Design model. For this particular project, Addie was chosen among others, due to the features highlighted in the succeeding sections.

3.4 ADDIE MODEL DEVELOPMENT

The Addie model is a systematic instructional design model consists of five phases: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. To date Addie has received extensive focus hence is always subjected to dynamic improvements that makes it more on a demand position by developers. Thus, several versions of the Addie model are available nowadays.

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The advantage of using Addie has been the linear process that it offers. This means that even though it is dynamic in nature, each phase is independent from the other. Due to its product orientation, the process of each phase needs not be repeated. Thus it is time saving. In chapter 3 and 4, the details of each phase are spelt out, while in Chapter 5, the implementation of the software that took place is presented.

In the Addie model, the profound feature is in how each single step has an outcome that feeds into the subsequent step. In other words, it deliberately attempts to save time and money due to the five phases of procedural development that are open for dynamic feedback before allowing the next phase to be proceeded.

Apart from that, specifically for education field, the Addie model has attracted many scholars in how it accurately interprets the objectives in the analysis stage. This characteristic made it easier for developers or even the researchers to achieve their objectives in proposing and developing a prototype. With regard to dyslexic children, this particular feature helps in quick adjustment of the raw materials, i.e. the 3D alphabet recognition tools, should the systems face faulty.

However, for researchers wanting to develop a whole application in the future, Hannafin and Peck model might be a better option since the processes are more beneficial for the users (students) than the facilitators (teachers). As such, Addie model is much more appropriate for a prototype development that has time constraint which became the limitation of this project hence justifies the Addie selection for this study.

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Due to the above advantage, Addie model is preferred by many application developers pertaining to learning attainment, (Aziz, Rasli & Ramli, 2010; Ronaldi Saleh Umar, 2011; Azizah Jaafar& Chan Siew Lee, 2012; Daud & Abas, 2013).

3.5 THE FIVE ADDIE MODEL EXECUTION FOR THREEDLEXIC

In this section, Addie Instructional Design Model that was used to design the ThreeDLexic is discussed according to the phase illustrated in the diagram below:

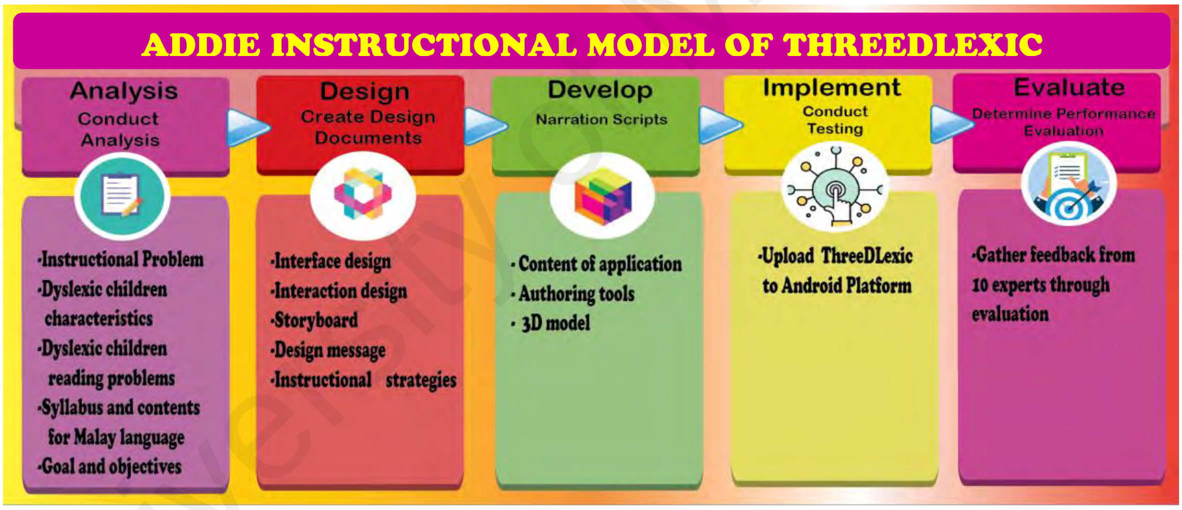

Figure 3.2 : Addie Conceptual Model Of ThreeDLexic

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i. Analysis

This phase requires the developers to clarify the instructional problem, goals and objectives explicitly. The developers analyse the learning environment while identifying the prior knowledge and skills of the learners. In other words, prior to software design and development, a need analysis was carried out to inform the areas that needed to be addressed in the newly developed software. This is to avoid repeating the weaknesses addressed in previous studies.

In so doing, the following questions are addressed:

- Who is the audience and their characteristics?
- Identify the new behavioral outcome?
- What types of learning constraints exist?
- What are the delivery options?
- What are the online pedagogical considerations?
- What is the timeline for project completion?

To achieve this aim, two types of data were used as the sources of information as follows.

Primary Data – Encompasses results of dyslexia screening test at PDM, data from the Instrument Screening Dyslexia, video records on observation of learning and teaching session in classrooms at the PDM center.

Secondary Data – analysis on the content of 2D application (contained in CD-ROM used in schools, center of dyslexia, government and private pre-schools), literature review on existing 2D and 3D (solely found in non-interactive video format, as discussed in Chapter 2) applications, books, journals, proceedings and content-rich websites via Internet webpage.

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In brief, the analysis stage is also the preliminary study whereby primary data were collected. Since the main aim of this study is first to determine which alphabet is causing problem to the children, the first step was to identify the letters that were perceived as problematic to these children. This procedure of identification was done by using the standard screening test or instrument used by all schools in Malaysia subjected to all 150 children in Year 1 to Year 3 at one government school in Peninsular Malaysia. Due to the standardized and established instrument used for the whole nation, the validity aspect of the instrument had been taken care of and therefore allowed the pilot study to be implemented without further unnecessary bureaucracy.

Thus, for the preliminary stage, responses from 150 dyslexic children who answered the standard instrument at schools served as the data, which were then analysed using Atlas-ti. The large sample is appropriate to gather broad data range as to feed into the breadth of the issues pertaining to the study's objective which to identify the problematic alphabets as perceived by the participants.

ii. Design

This phase requires systematic and specific procedure as it deals with crucial aspects of the software contents - the learning objectives, assessment instruments, exercises, content, subject matter analysis, lesson planning and media selection. It should be systematic since the learning objectives demand a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the project's goals. Specific means each element of the instructional design plan needs to be executed with attention to details.

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Thus, throughout the phase, needful areas were successfully identified in considering the design of the new software. These include the interface design, interaction design, storyboard, design message and instructional. These are the steps used for the design phase:

- Documentation of the project's instructional, visual and technical design strategy
- Apply instructional strategies according to the intended behavioral outcomes by domain (cognitive, affective, psychomotor).
- Create storyboards
- Design the user interface and user experience
- Prototype creation
- Apply visual design (graphic design)

Based on the analysis obtained, discussion on the design is presented in Chapter 4.

iii. Development

This is a phase where developers create and assemble the content assets that were created in the design phase. For instance, during this phase, programmers labor their effort to develop and integrate technologies while testers commit debugging procedures. The project is constantly reviewed and revised according to any feedback given.

In this study, the software was developed using practical authoring tools available at no cost. These are Unity3D and 3D Max, capable of integrating media elements such as texts, graphics, 3D models, animation, audio and video. The selection of these authoring

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tools involved careful considerations as the processes involved were inevitably time consuming. The development phase is elaborated further in Chapter 4.

iv. Implementation

The implementation phase is a test field for the software. This is also a main data collection field whereby observations on the children using the software were done and opinions from the experts and the teachers were also gathered. To do this, the software was uploaded onto the android platform. This process is crucial as to ensure no faulty occurred during the evaluation phase. Due to multiple versions of android available, a few series of run tests were required as to match the most compatible configurations of the android settings with the newly developed prototype. Careful procedural steps were taken into considerations such as notification of potential crash of animations due to load of movements and overlap of graphics on a congested space. Thus, series of implementation phase include pilot tests before actual take off was executed on the software.

Apart from that, the implementation phase also involved developing a procedure for training the facilitators and the learners. The facilitators' training should cover the course curriculum, learning outcomes, method of delivery, and testing procedures. In this case, facilitators were the teachers at PDM who were involved in observing the children. Preparation of the learners includes training them on new tools (software or hardware) and student registration. Normally, in software development, this is also the phase where the researcher ensures that the books, hands on equipment, tools, CD-

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ROMs and software are in place, and that the learning application or web site is functional.

v. Evaluation

Evaluation may be considered as a reflection stage whereby all the data gathered were given careful scrutiny and investigations. In general, the evaluation phase consists of two parts: formative and summative. Formative evaluation is present in each stage of the Addie process. Summative evaluation consists of tests designed for domain specific criterion-related referenced items and providing opportunities for feedback from the users.

In this particular study, the primary source of information came from the ten experts of whom encompass two wide categories: five experts in dyslexia and another five were from educational technology background. This combination of expertise ensures a counterbalance of all possible areas of improvement and maintenance. They were given questionnaire created via online method i.e. Surveymonkey. These were done after all the experts were asked to test the prototype. Their suggestions were all considered. All possible solutions were opted whenever problems emerged. This phase is further explained in the next chapter.

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3.6 THE PARTICIPANTS

As this is a mixed method research in nature aiming at achieving the research objectives, four groups of participants were involved at the different phases of software development. This decision also serves to fulfill the triangulation purpose at a later stage. To depict the stage and the respondents involved at each stage of data collection, Figure 3.3 is presented below.

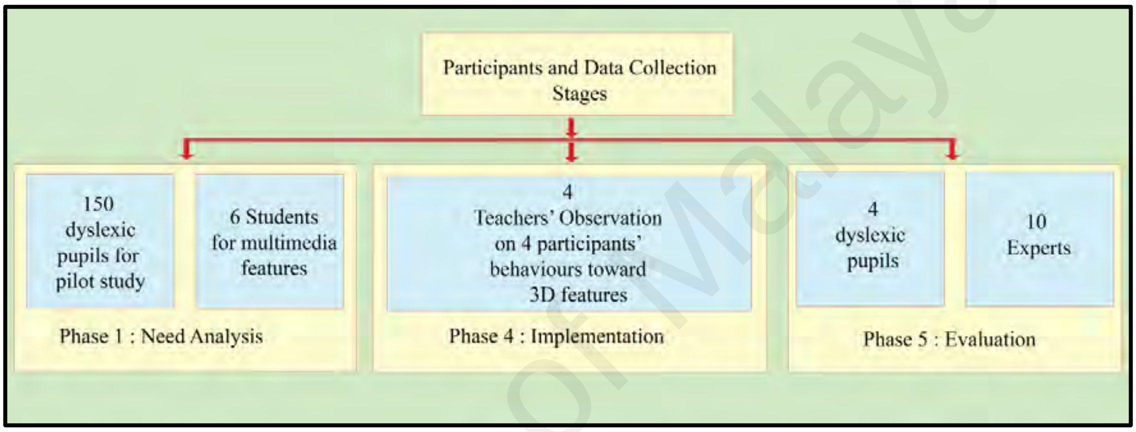

Figure 3.3: The Participants Involved In The Research

3.7 DYSLEXIC CHIDREN

The target participants for this study are children having reading and learning difficulties known as dyslexic children in Malaysia. Coincidentally, as explained in Chapter One, my duty as a teacher attached to special need class, coupled with my part time job as a facilitator at PDM allows me the opportunity to work closely with the dyslexic children.

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The dyslexic children participants were divided into two groups. The first group comprising 150 participants served as the unit of analysis for the pilot study. Another four children involved during the prototype test. Two of them were subjected to the 3D prototype while another two who served as a control group, were subjected to 2D application.

3.8 THE EXPERTS AND TEACHERS

In order to gain insights on the rectifiable areas of the prototype, a group of ten experts were assigned to evaluate the prototype. They consist of lecturers and teachers in the field of research related. Their expertise has been used to make prototype assessments in terms of the use of multimedia elements.

3.9 PROCEDURE OF DATA COLLECTION

The data collection has been discussed while explaining the phases of Addie above. In brief, there are two data collection phases involved:

First phase (preliminary stage): to identify problematic alphabets. Second phase (implementation stage): prototype testing to the participants including the experts and the teachers. During the second phase whereby the software was tested, four dyslexic children from Persatuan Dyslexia Malaysia (PDM) served as the unit of analysis. Their selection was based on the recommendation from their class teachers by referring to their Bahasa Malaysia performance. These four children were divided into two groups. The first group was the focus group that learnt the alphabet using the newly developed

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3D prototype and the second group comprising two children was treated as the control group who used the 2D application.

The validity and reliability of the data were further bolstered with the participation of teachers who teach dyslexic children. Four teachers worked together with the researcher during the data collection process. Records were filled into the log form identical to those used during the analysis phase. Furthermore, after the development of the ThreeDLexic prototype, it was sent to 10 experts for assessments to ensure that the application is suitable for the use of dyslexic children (**APPENDIX A**). A detailed explanation by the research participants will be presented in the next sub-topic. The demography of the participants is tabulated in Table 3.1 below.

Table 3.1 : Demography of The Participants

Participants	Gender	Age (years old)	Institution	Experience (years)	Expertise
150-pilot study	M: 56 F: 94	7 to 9	Government School	NA	NA
10 Experts	M: 1 F: 9	21 to 73	Government :7 Private : - NGO: 3	2 to 50	Application Technology : 5 Dyslexia Pedagogi : 5
4 dyslexic children for Focus and control group	M:2 F:2	6 to 9	PDM	NA	NA
4 Teachers and 6 dyslexic pupilss for evaluation	M: 4 F: 6	6 to 45	PDM	Teachers: 2 to 3 Student:- NA	Teachers : Teaching dyslexic Student :- NA

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3.10 DATA INTERPRETATIONS WITH FUZZY DELPHI METHOD (FDM)

Fuzzy Delphi Method (FDM) is a technique and measurement instrument rebranded from Delphi technique (M. Ridhuan M. Jamil & Siraj S., 2014). The pioneer academicians responsible for the introduction of this technique were Murray, Pepino and Gigch in 1985. FDM is capable of:

a) Clarifying items of prediction and respondent's information content.

b) Clarifying individual characteristics of participants.

In short, FDM is used to obtain consensus from experts who acted as respondents based on the use of qualitative analysis. FDM is time and cost efficient and allows the experts to express freely their opinions, which may in turn ensure consistency and competency.

For FDM analysis, a questionnaire was developed by the researcher based on the literature in the field of computer science and special needs education. The second step was to obtain the consensus of the experts on the elements of the 3D learning prototype. The experts comprised five Computer Science lecturers and five special needs teachers teaching dyslexic children at an NGO with more than 10 years' experience in the related field. Table 3.2 shows the simpler FDM technique for determining the elements of 3D prototype based on the experts' consensus for the questionnaire. The steps used in determining the FDM are given below.

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Step 1: Determining the experts. 10 experts were invited to answer the questionnaire.

Step 2: Selecting a linguistic scale. The researchers chose a 5-point Likert scale ranging from ‘strongly disagree’, ‘disagree’, ‘less disagree’, ‘agree’ and ‘strongly agree’. Table 3.2 shows the five-point likert scale and the difference to that of Fuzzy Scale.

Step 3: Getting the average value, d. The average value was determined according to the formula described below, before it was interpreted.

Table 3.2 : The Difference Between Likert Scale and Fuzzy Scale for 5 Point

Fuzzy Scale (FDM)				**Scale of Agreement**		**Likert Scale**
0.6	**0.8**	**1**		**Strongly Agree**		**5**
0.4	**0.6**	**0.8**		**Agree**		**4**
0.2	**0.4**	**0.6**	⇦	**Less Disagree**	⇨	**3**
0	**0.2**	**0.4**		**Disagree**		**2**
0	**0**	**0.2**		**Strongly Disagree**		**1**

There were three conditions by which the average value, d may be used in making interpretations. These are;

- Condition 1: Based on a-cut > 0.5 item is acceptable if a-cut < 0.5 will not be accepted as a threshold value (Tang & Wu, 2010; Bodjanova, 2006).

$$A_{max} = 1/3 * (m_1 + m2 + m3)$$

- Condition 2: The use of Threshold Value, d (Chen, 2000; Cheng & Lin, 2002) as summarized below:

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$$d(\bar{m}, \bar{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]}.$$

That is Threshold value $d \leq 0.2$ of item is acceptable and if threshold value of item is >0.2 it will not be accepted or a second round will only take into account of experts which is not in agreement.

- Condition 3: Based on the Traditional Delphi Method (Chu & Hwang, 2008; Murry & Hammons, 1995) where, percentages of agreement in a group of experts must be > 75%.

3.11 SUMMARY

This chapter expands on the methods involved in designing and testing of the prototype. It outlines the Addie Model that guides the needful procedure of a software development starting from the identification of the problem to the evaluation of the software, while elaborating the participants involved. The next chapter brings into conversation the findings from the data collection and analysis.

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CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.1 OVERVIEW

This chapter extends a discussion on the analysis of the first data collection stage that is the analysis phase of Addie. This stage is crucial as it serves as a heuristic device to gauge the appropriate design and development pertaining to the content of the prototype. In particular, the objective of this analysis is to identify the problematic alphabets to be included as the learning content and learning objective of the developed 3D-assisstive reading prototype. The first data collection was executed while in the first phase of Addie by which an analysis was done to detect the problematic alphabets perceived by the participants. This chapter acts as a foundation to understand the needful design and proper development of the ThreeDLexic prototype that will be elaborated in the next chapters.

4.2 DATA COLLECTION 1: CONDUCT ANALYSIS (PHASE ONE ADDIE)

As mentioned in the previous chapters, Addie is an acronym for the five stages involved in designing and developing a software or an application that stands for Analysis, Design, Develop, Implement and Evaluate as depicted in the following figure 4.1.

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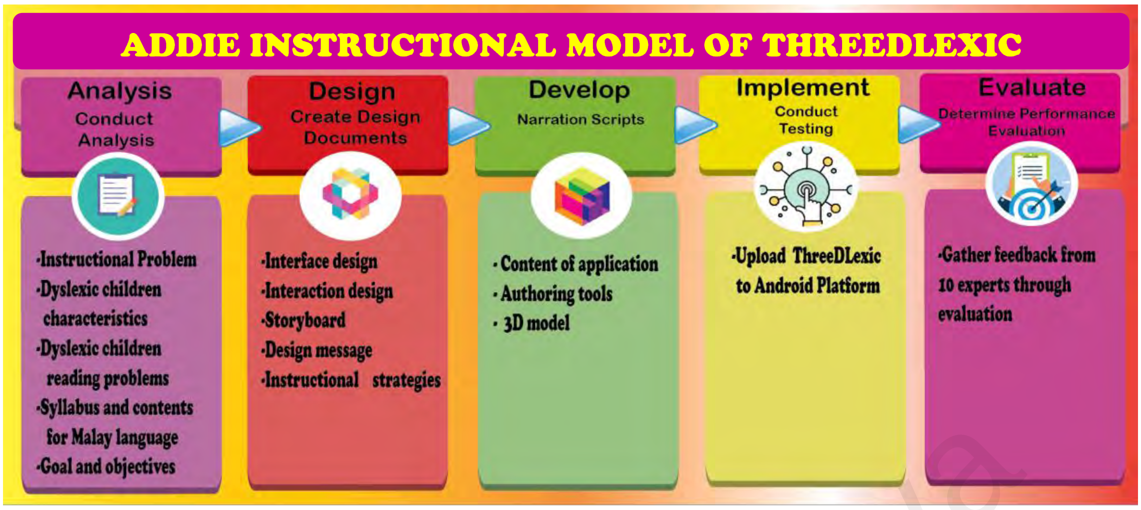

Figure 4.1: Addie Instructional Model Of ThreeDLexic

The first phase is an analysis stage that tries to diagnose the instructional problem, dyslexic children characteristics, dyslexic children reading problems, syllibus and contents for Malay language subject. The second phase i.e design stage is a process where it involves interface design, interaction design, storyboard, design message and instructional strategies. The third phase is the development phase involving narration scripts such as content of prototype, authoring tools and selection as well as building 3D models. In the fourth phase i.e implementation, a trial is conducted where the prototypes is uploaded onto the android system to be tried by the participants in this study. The final phase is an evaluation that gathers feedback from ten experts after they have experienced the software by themselves.

4.3 IDENTIFY REVERSAL LETTERS

In this phase, the objective is to identify the few alphabets that are perceived to be problematic by the participants. Therefore, a screening test was conducted involving Year 1, 2 and 3 pupils from two schools: Sekolah Kebangsaan Seri Angsana and Sekolah Kebangsaan Seri Kemboja (pseudonym for school for data protection act). In

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this phase, the test or the instrument has five parts namely Specific Difficulties, Behaviour, Learning Difficulties, Writing and Language. This instrument is inevitably important to determine that the issue of children suffering from disorder as claimed by earlier researchers exists. The main aim of the analysis is to identify the reversal letters suffered by the students, thus this aspect was primarily analysed from the instrument. To ensure robust data collection and to allow for triangulation at a later stage, observation on the students and interview sessions with their teachers were also conducted. This is to ensure that all evidences and information could allow researcher to determine whether "strephosymbolia" (Gay 2001) among these participants exist. "Strephosymbolia" means a learning disorder in which symbols and especially phrases, words, or letters appear to be reversed or transposed in reading. While so doing, the findings from previous studies pertaining to reversal letters that have been identified by the previous researchers found in the essay form were constantly referred to (Gay, 2001).

Throughout the analysis, a total of 115 files in JPEG format were recorded for further analysis to identify the affected letters. The data was subjected to qualitative analysis using Atlas Ti software. Drawing from the analysis, there were five categories of reversal letters identified as below:

- Reversal letter for lower case b and d
- Reversal case for lower case p
- Reversal letter for case w and m
- Reversal letter for lower case n, u and v
- Reversal letter for lower case s and z

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By using the Atlas.Ti, data was studied and five diagrams were generated. From these diagrams (Figure 4.2), specific letters were selected to be 3D subjects in the ThreeDLexic prototype. The result is depicted in Figure 4.2.

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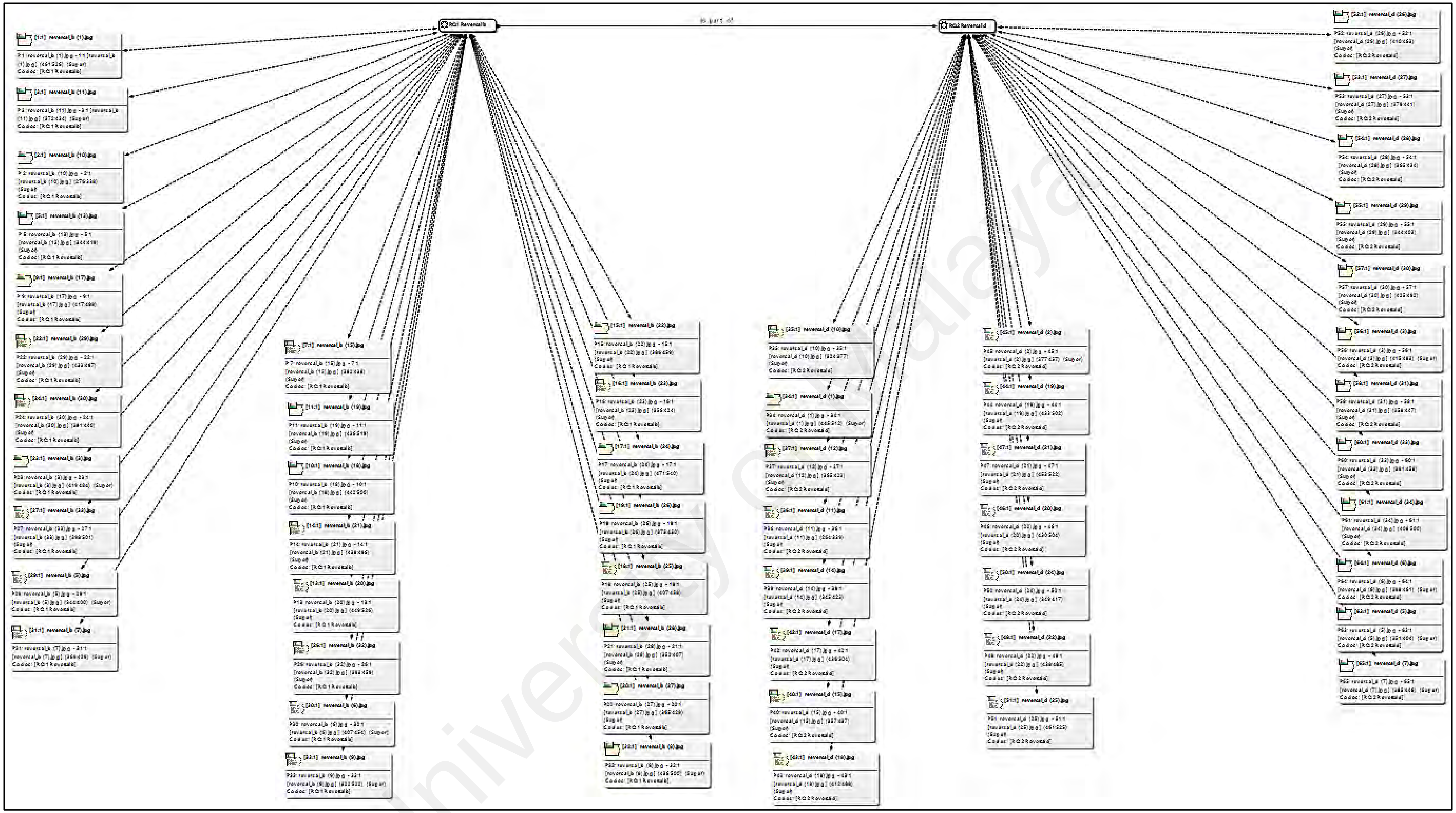

Figure 4.2 : Diagramfor Reversal Letters for Lower Case ‘b’ and ‘d’

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By scrutinising Figure 4.2 it was found that there were 27 mistakes occurred in conjunction with letter ‘d’. During the screening test students tended to choose letter ‘b’ instead. Similarly, for the lower case ‘b’, 27 mistakes were encountered during the screening test. These findings ascertained that both lower case letters ‘b’ and ‘d’ should be transformed as a 3-dimensional object in the proposed prototype.

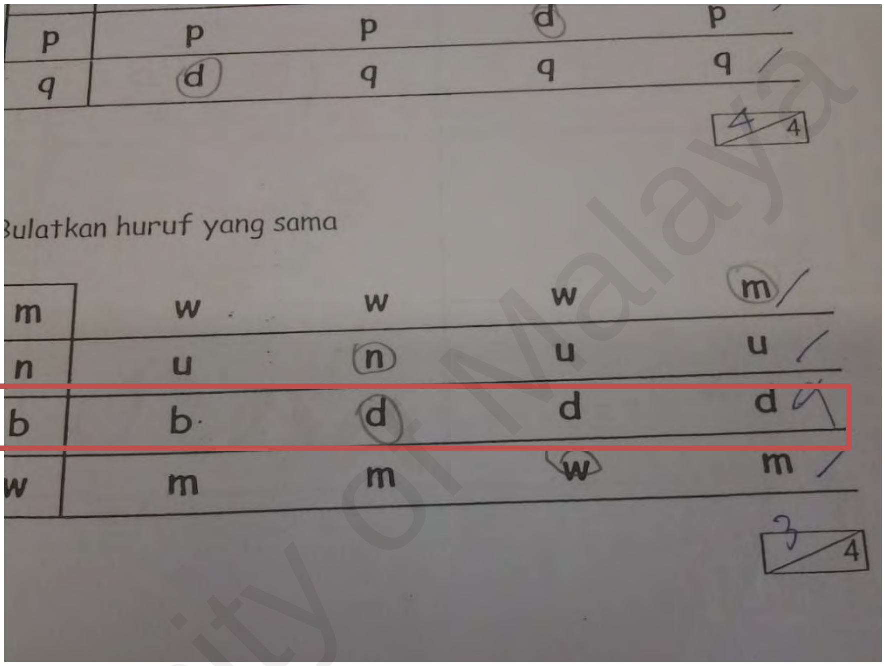

Figure 4.3 : The sample Paper From Screening Test in Pilot Study for letter ‘b’

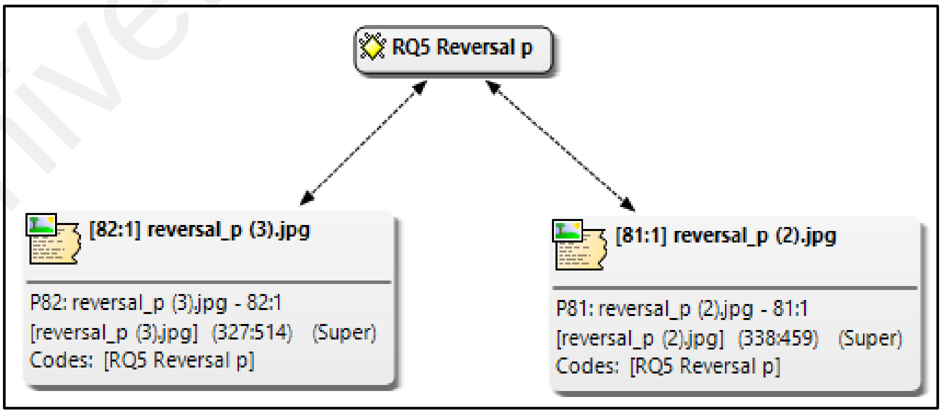

Figure 4.4 : Diagram For Reversal Letters For Lower Case ‘p’

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For lower case ‘p’ (Figure 4.4 and Figure 4.5), there were two cases detected. In this regard, even though the case seemed trivial, it gradually became complicated when students kept writing letter ‘p’ in reversed manner repeatedly during the whole screening test. Thus, lower case ‘p’ was included as a 3D object.

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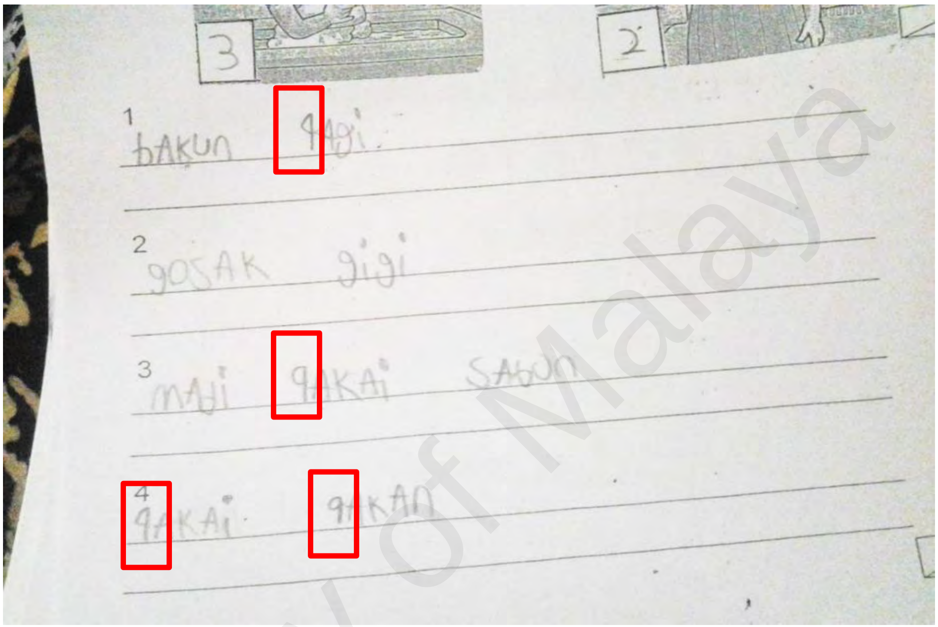

Figure 4.5 : Sample Of Student’s Work During Screening Test Showing Letter ‘p’ In Reversed Form

The diagrams (Figure 4.6 and Figure 4.7) was from an analysis for lower case ‘w’ and ‘m’. There were six cases of wrong selection reported during the same screening test. Thus, letters ‘w’ and ‘m’ was also included as a 3D object in this research.

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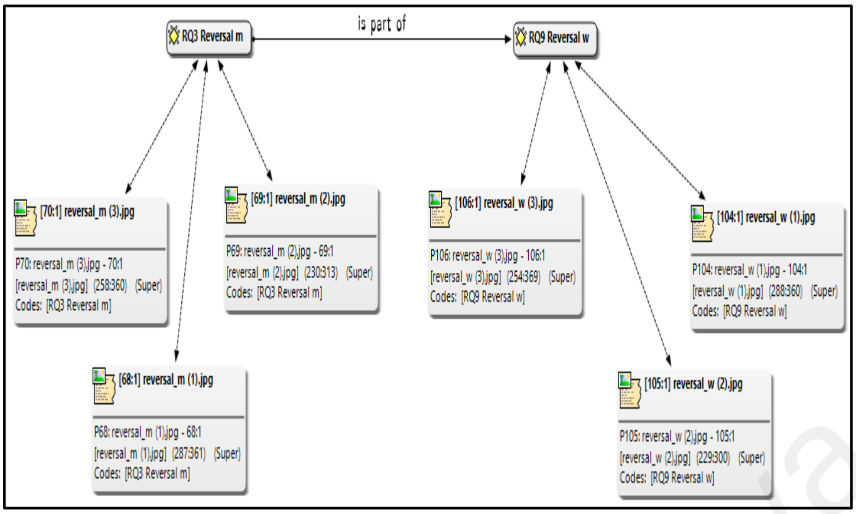

Figure 4.6 : Diagram For Reversal Letters For Lower Case ‘m’ and’w’

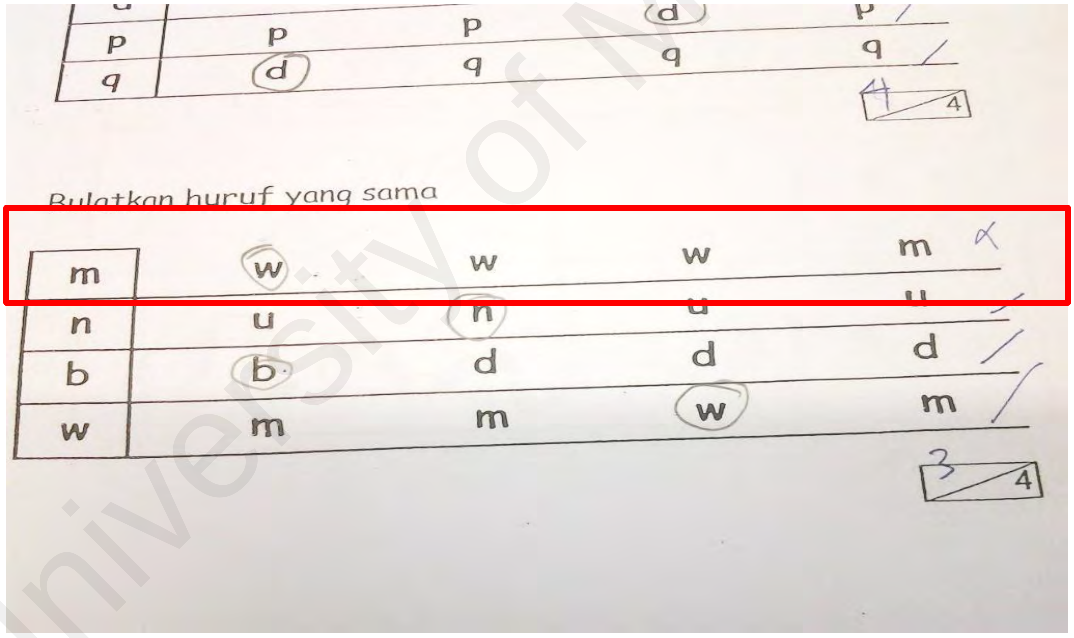

Figure 4.7 : Sample Of Student’s Work From Screening Test In Pilot Study Showing Wrongly Selected Letter For “m”

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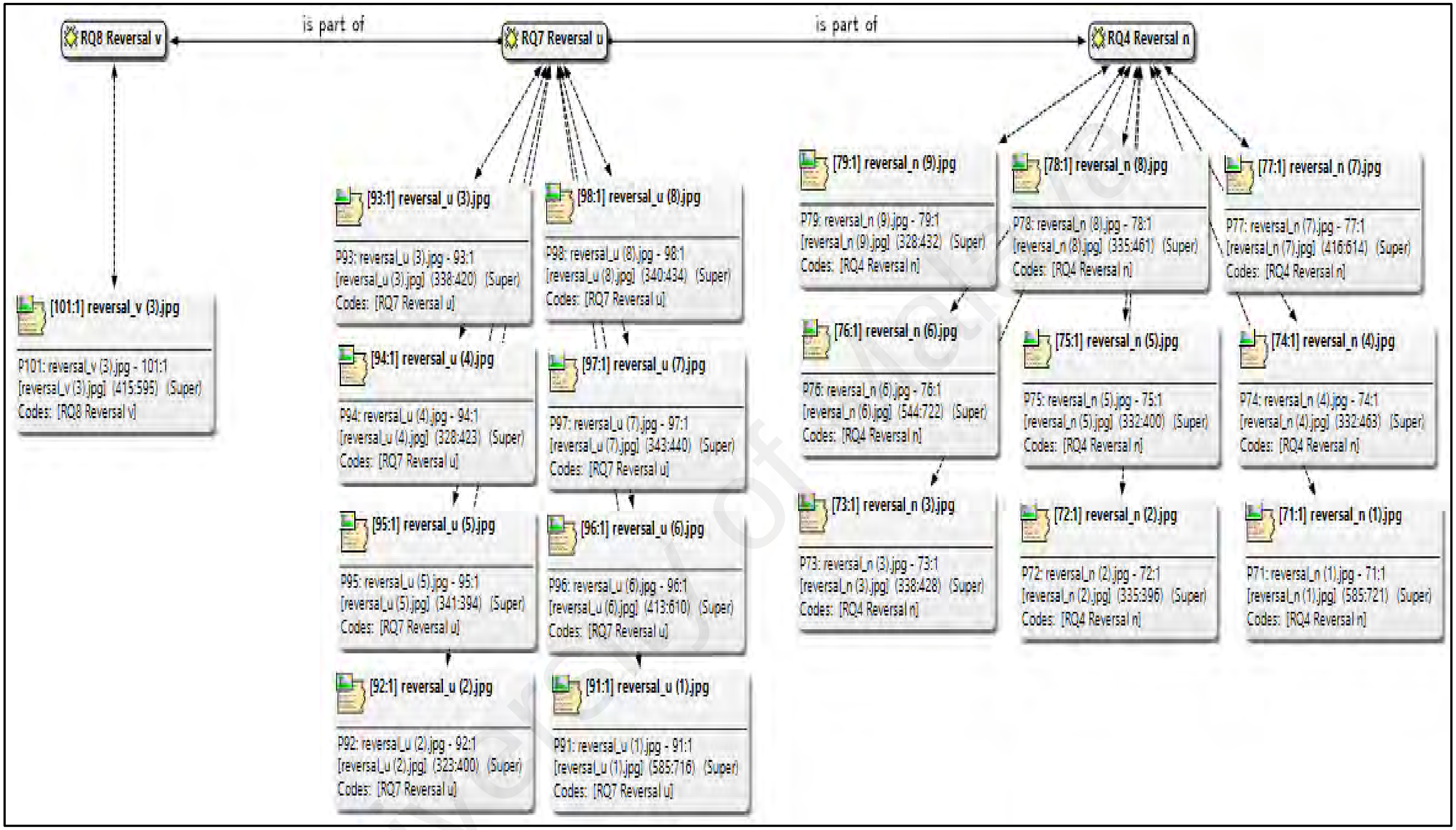

Figure 4.8 : Diagram For Reversal Letters For Lower Case ‘n’, ‘u’ and ‘v’

The diagrams (Figure 4.8 and Figure 4.9) was from an analysis for lower cases ‘n’, ‘u’ and ‘v’. There were 18 cases encountered. So these letters were included as part of the 3D objects to be created in the prototype.

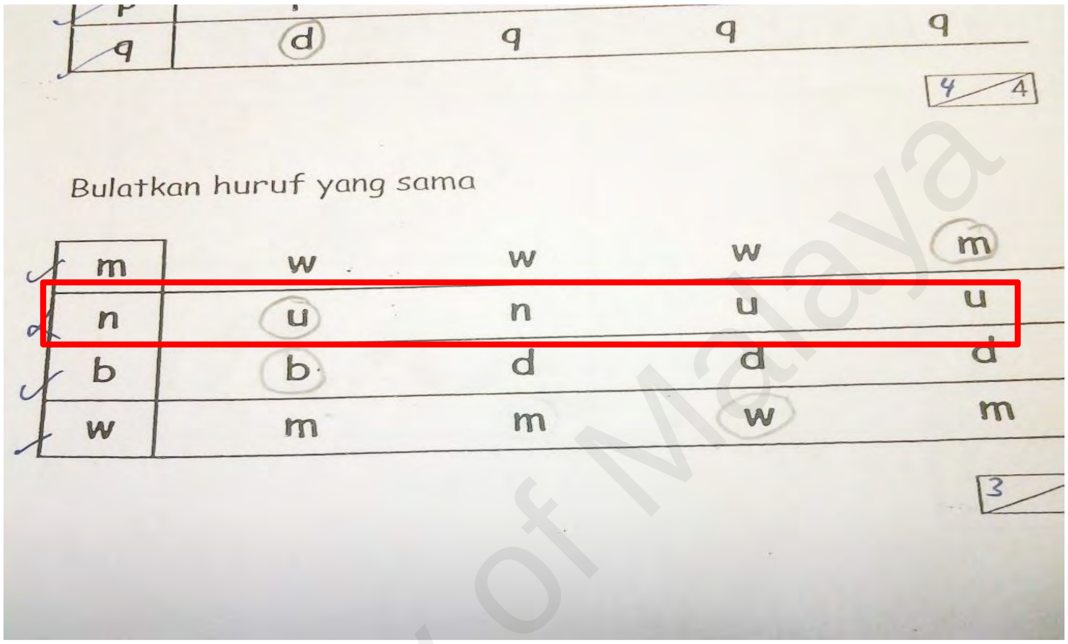

Figure 4.9 : Sample Of Student’s Work From Screening Test In The Pilot Study Showing Wrongly Identified Letter For ‘n’

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For lower case ‘z’ and ‘s’, the diagram (Figure 4.10) shows:-

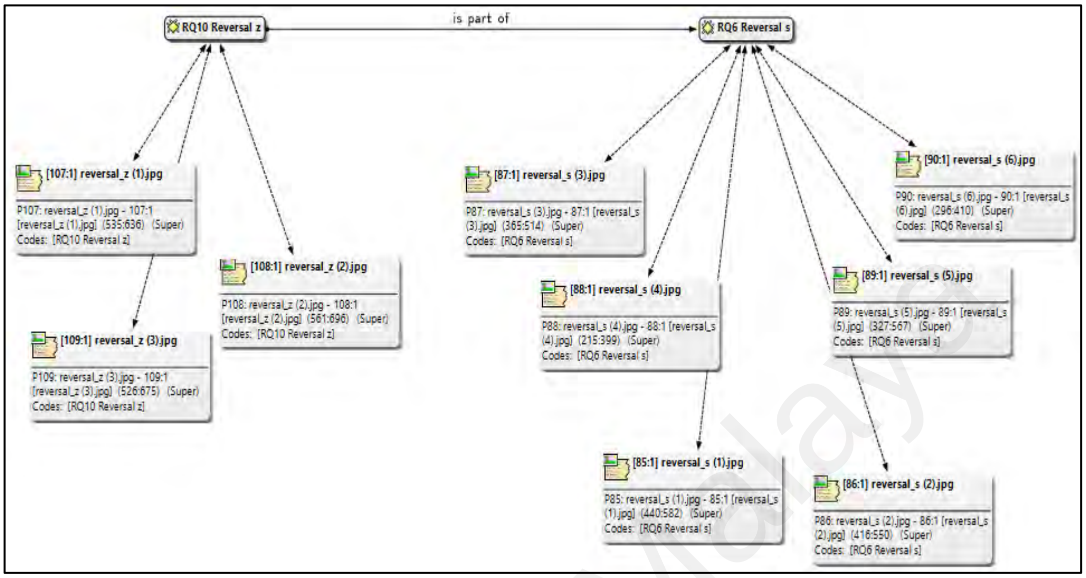

Figure 4.10 : Diagram For Reversal Letters For Lower Case ‘z’ and ‘s’

Figure 4.10 illustrates the lower cases ‘z’ and ‘s’. There were six cases of mistakes found in the screening test. Hence, these two letters were also included as the content focus of 3D objects in this research.

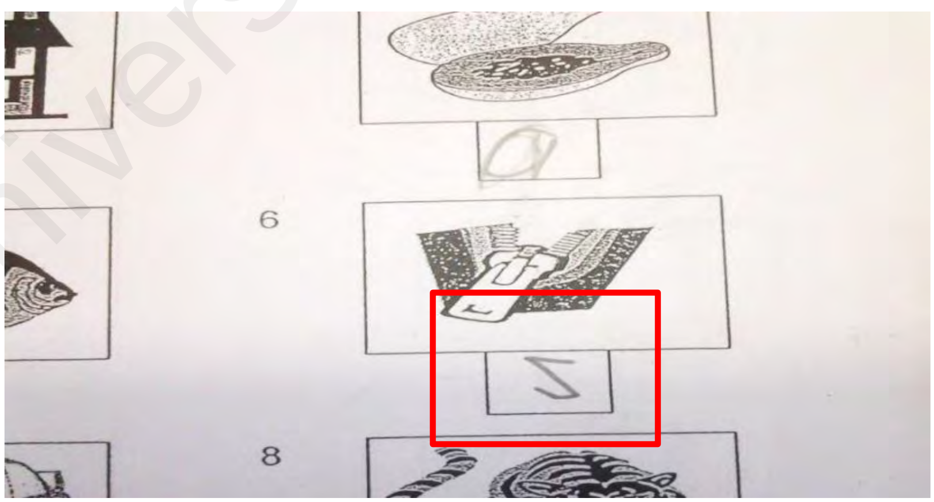

Figure 4.11: Sample of student’s work From Screening Test In The Pilot Study Showing Reversed Letter ‘z’

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4.4 DYSLEXIC CHILDREN REACTION OBSERVATION

Apart from the analysis on the affected letters involved in the development of the prototype, the analysis on student's reaction through observation was also performed. The objective is to see what aspects influence participants' reaction towards the prototype. At this stage, a total of six dyslexia pupils were selected as the research subjects. All data was recorded in the form of video and the whole duration was approximately 2 hours and 30 minutes in a series of learning and verbal screening sessions.

Observation were analysed using a form based on four main criteria. The criteria was derived from findings suggested by Salman Firdaus Sidek et al. (2014) which are types of instruction, types of color, types of level and multimedia elements to be used. Their study has revealed these four aspects as influencing the children's behavior towards the learning of alphabets. This form was also previously used by Davis et al., (2007) in his research on autistic children. In this present study, the form was modified to suit with the objectives. **(APPENDIX C).**

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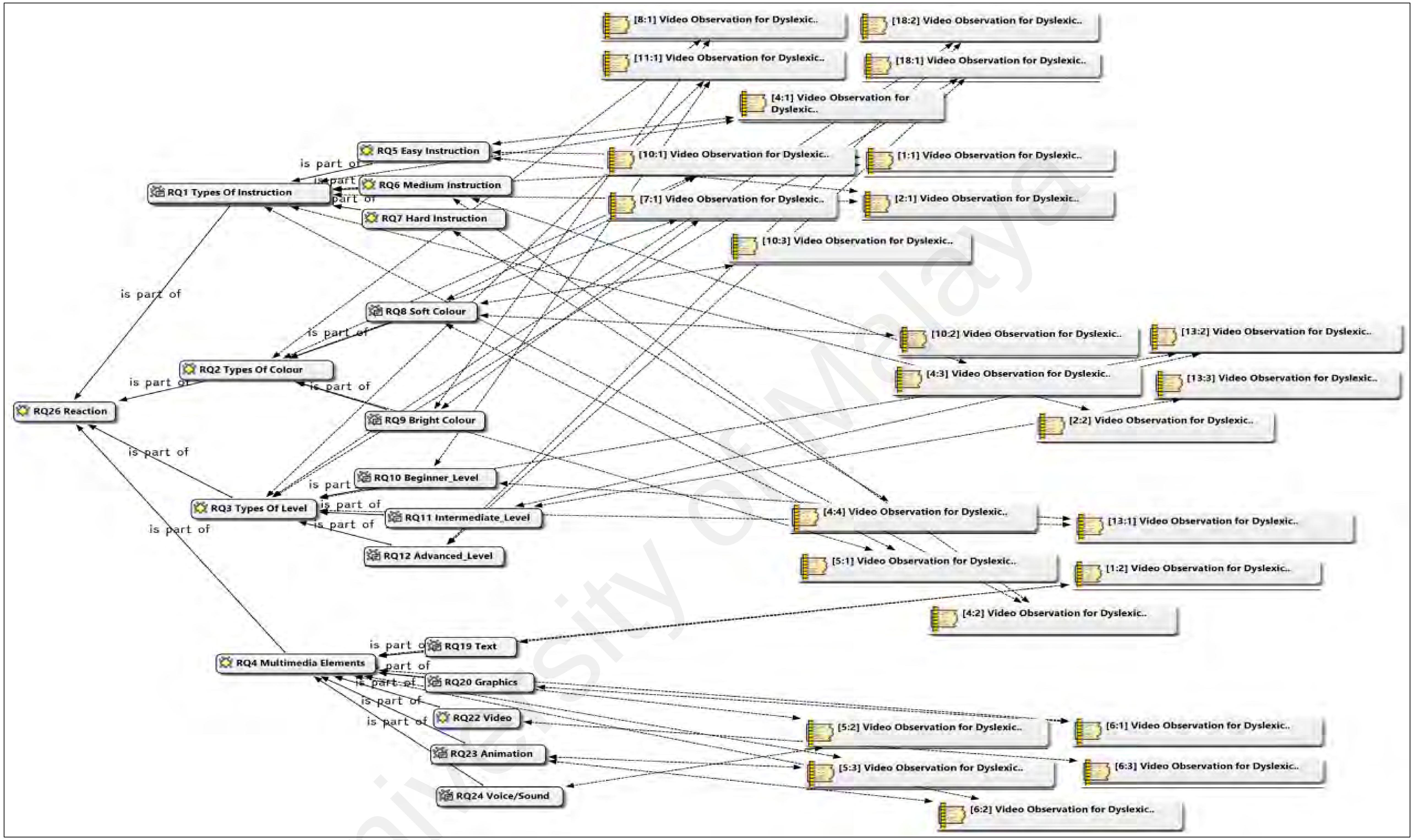

Figure 4.12 : Diagram Recorded by Video For Student Reaction

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After their behavior/responses were recorded, the video was analysed by executing Atlas.Ti and the result is shown in Figure 4.12. From the figure, a few interesting findings emerged. For instance, under 'type of instruction', there are three levels provided in the prototype i.e easy, medium and difficult (labeled as 'hard') instructions. The easy instruction is signified by simple target of behavior such as "create vocal letters" from teachers. The medium instruction is exemplified by behavior of "listen to the sound of letters that I make and try to make it". While for the difficult (hard) instruction, reaction towards instruction that is, "look at the letters that I wrote and try to do it", was the target to be observed. The way their behavior was analysed lies in the time taken to response to these instructions i.e whether it was a quick or delayed response.

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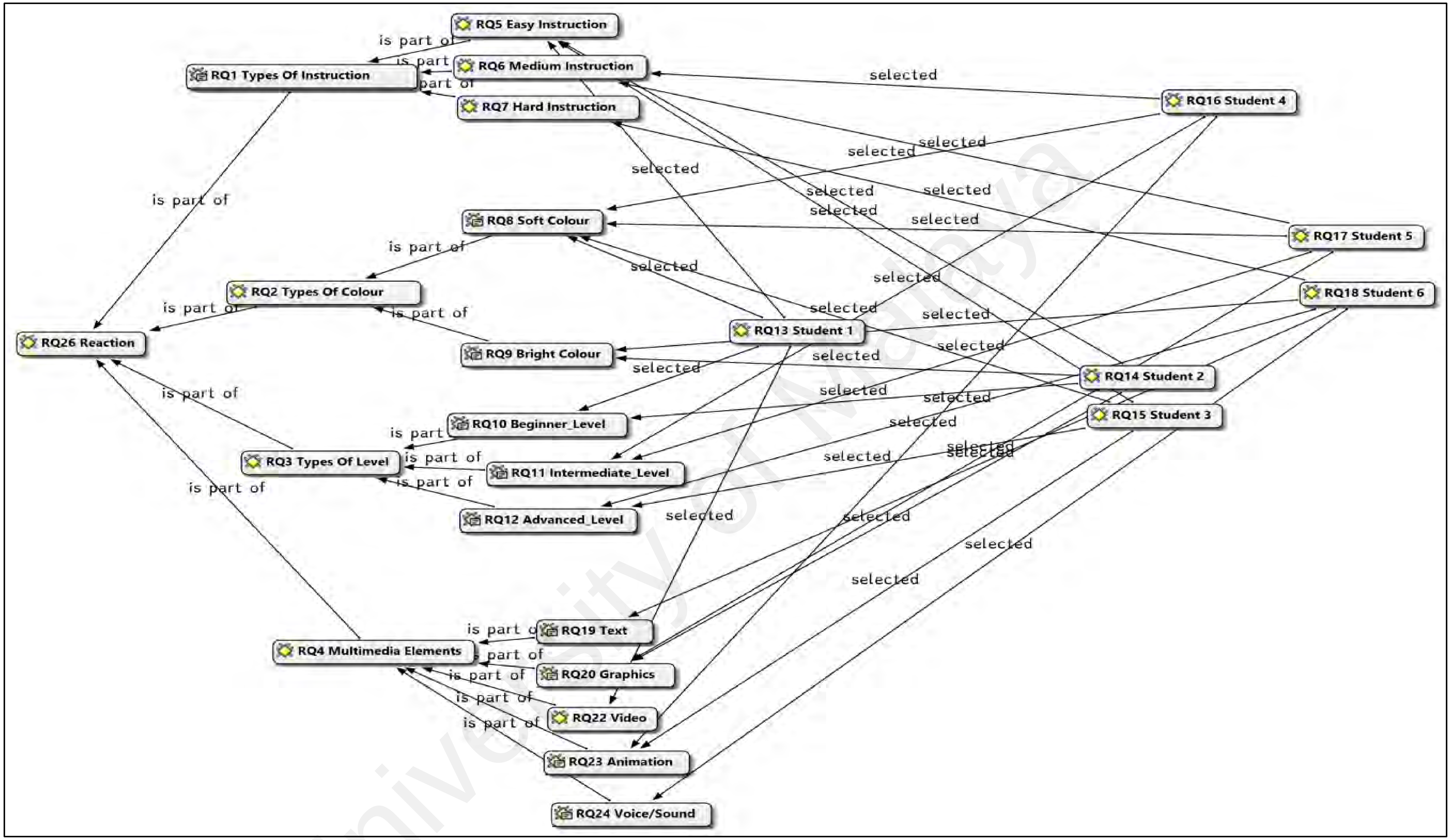

Figure 4.13 : Analysis on the Individual Participant's Reaction on the Evaluated Aspects

Referring to Figure 4.13, participant ('student' as in the diagram) 1, 2 and 3 provided a quick response to easy instructions such as "create vocal letters" from teachers. In the mean time, for medium instructions, i.e "listen to the sound of letters that I make and try to make it", students 4 and 5 provided quick responses. As for the difficult (hard) instruction such as " look at the letters that I wrote and try to do it", student 6 provided a quick response.

The second aspect was the type of colors which was categorized as soft and bright. The behavior towards this aspect was observed while participants were using the existing 2D application. Dyslexic pupils 1, 3, 4 and 5 provided positive responses to the use of soft colors in the 2D application. Meanwhile, students 2 and 6 provided positive response to the use of bright colors.

The third aspect was the difficulty level of content i.e the how difficult or complex was the learning content. For this, three levels of content were set up ie beginner, intermediate and advanced levels. Based on the analysis, student 1 and 2 reported positive response for the beginner level. While, for intermediate level, students 4 and 5 reacted positively. Students 3 and 6 demonstrated positive response for the advanced level.

The multimedia elements that were used in the ThreeDLexic were divided into text, graphics, video, animation and voice/sound. Students' reactions were video recorded while they were using the existing 2D application. The results show that student 5

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reacted positively to text, while student 2 and 6 provided a positive response to the use of graphic elements. While elements of video generated a positive reaction from student 1. As for the elements of animation, students 3 and 4 reacted positively. While student 6 responded positively to the elements of sound or voice.

4.5 REVERSAL LETTERS ANALYSIS

The objectives of this part is as follows:

a) To identify letters which were often written in reversal by dyslexic pupils

as shown in Figure 4.13, 36% participants wrote ‘b’ and ‘d’ in reversal, 1.3% wrote ‘m’ and ‘w’ in reversal, 12% having difficulty with letters ‘n’, ‘u’ and ‘v’, 8% with letter ‘p’, for ‘s’ and ‘z’ 6% and 36.7% for other letters.

The findings from Figure 4.14 were concurrence with other studies (Manzura, 2009; Husni &Jamaludin, 2013; Skiada et al., 2014).

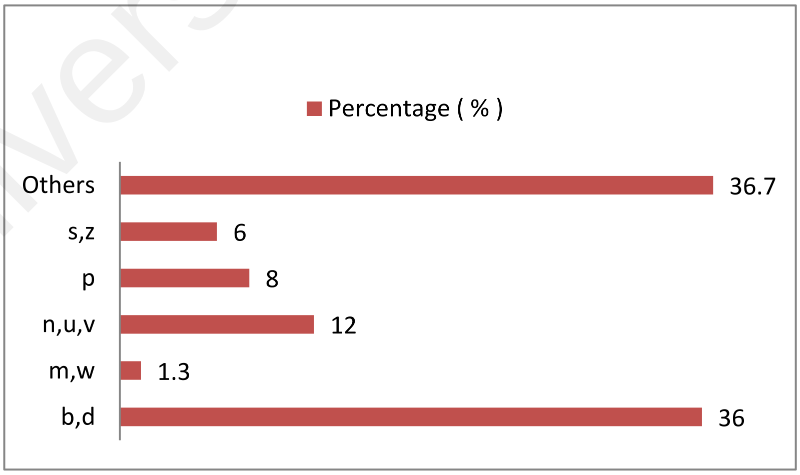

Figure 4.14 : Letters Result Graph

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4.6 DYSLEXIC CHILDREN REACTIONS OBSERVATION ANALYSIS

The main objectives of this part is to determine types of multimedia elements that should be used in the development of proposed prototype.

Table 4.1 : Dyslexic Children Reaction on Types of Elements

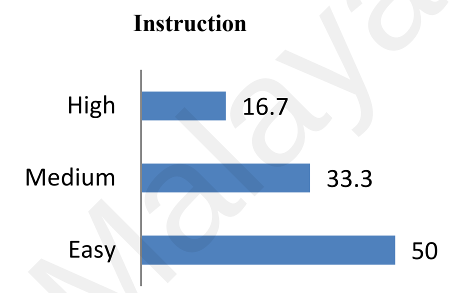
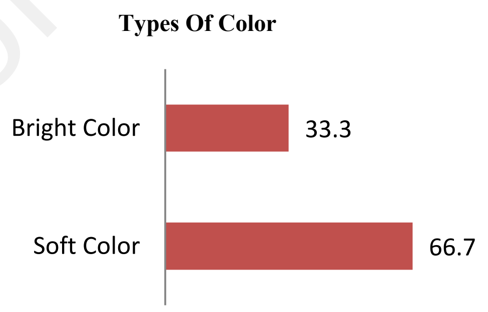
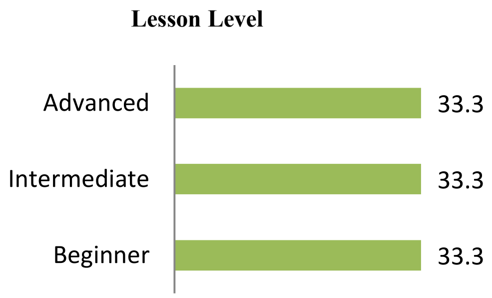
No	Types Of Element	Percentage
1.	Instruction Easy Medium High	
2.	Color Soft Color Bright Color	
3.	Lesson Level Beginner Intermediate Advanced	

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Table 4.2 : Continues : Dyslexic Children Reaction on Types of Elements

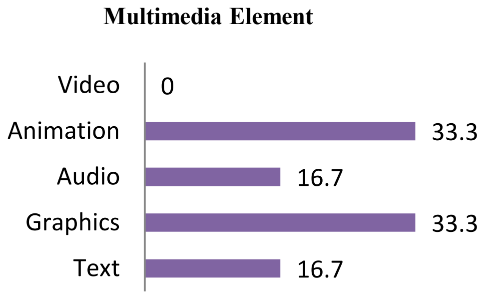
No	Types Of Element	Percentage
4.	Multimedia Element Text Graphics Audio Animation Video	

Table 4.1 and Table 4.2 show findings from the instructions data. It demonstrates that 50% of the participants were able to follow the easier instructions, 33.3% for medium instructions and 16.7% for high level instructions. This shows that most participants were able to follow easy instructions.

For colour selections, research conducted by Husni and Jamaludin (2013) used a combination of soft colour scheme. This was in tandem with the finding from the present study that soft colors were selected by 66.7% of the participants compared to the bright colours with only 33.3%. Therefore, the proposed prototype will be using more soft colours combination compared to the bright colours combination.

The lesson element was divided into three levels: beginner, intermediate and advanced levels. Each level recorded a 33.3% selection from the analysis made. Based on this, all three levels of the lesson were incorporated in the development of the ThreeDLexic prototype.

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Finally, findings from student's reaction from the initial data before the development of the 3D prototype for multimedia element were as follows: text 16%, graphics 33.3%, animation 33.3% and audio/voice recorded 16.7%. There was no selection from participants on video because this element was not used in the 2D application. Research done by Siti Zulaiha Ahmad and Noor Izzati Jinon (2013) suggested that the elements should be included equally into the teaching and learning application.

4.7 SUMMARRY

This chapter discusses the analysis executed on the data which was collected during the analysis phase (ie the first phase of the model development, Addie). Drawing upon the findings, a foundation for the content development of the 3D prototype has at least been figured out. The next chapter will elaborate on the further design and development of the prototype.

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CHAPTER 5

PROTOTYPE DESIGN AND DEVELOPMENT

5.1 OVERVIEW

This chapter describes the steps involved in developing the ThreeDLexic software that is enabled via a mobile application namely the android platform. It elaborates on the system requirements to build the application, the application design, the interface and the content development. Careful considerations that took place in designing and developing the application to suit with the end users' orientation is elucidated.

5.2 SPECIFICATION OF PROTOTYPE REQUIREMENT

In developing the prototype, the specifications required for the prototype must be related to the users' orientation. The prototype specification contains functional requirements and nonfunctional requirements in additions to use cases. The following Figure 5.1 and Table 5.1 visualise the technology architecture and the criteria to develop a mobile-based application.

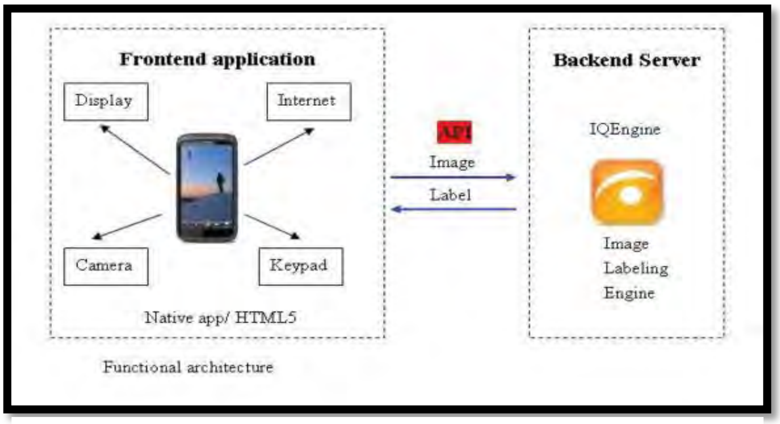

Figure 5.1 : Technology Architecture

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Table 5.1 : Criteria in the Development of Mobile Based Application

Criteria	Sub-criteria
Development Environment	Programming language
	Support from community
	Code editor
	Debugger
	Testing
	Deployment
	Distribution
Functionality	SDK
	Hardware interface
	Built-in app interface
	Web service interaction
	User interface builder

5.3 DEVELOPMENT ENVIRONMENT

- **Programming language**: This sub-criterion tells both about the simplicity and the popularity of the programming language. For example Java is less challenging than C and also more popular due to the bigger community of the Java programmer.
- **Support from community**: This sub-criterion is about how much help developers could receive from community, for example, the tutorials, development tools and troubleshooting.
- **Code editor:** This sub-criterion is about the quality of the code editor adopted for the application development. A good code IDE (integrated development environment) will provide immediate feedback with error messages and warnings, quick fix feature, content assistant and a good guidance document.

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- **Debugger**: This sub-criterion tells about how powerful and applicable the debugging tools are. A robust debugging tool will help manage break point, trace object value through the code and identify unexpected bugs.
- **Testing and emulator:** This sub-criterion show how effective the testing of apps on an emulator is. A powerful emulator will run fast and support as many device's features as possible, such as GPS, camera, and accelerator.
- **Deployment:** This criterion relates how straightforward it is to deploy and update an app onto a real device.
- **Distribution:** This sub-criterion shows how easy it is to distribute an app to multiple platforms with app store or without app store.

5.4 FUNCTIONALITY

- **Software development kit (SDK)**: This sub-criterion shows the ease of downloading and installing the SDK, and the applicability of the SDK.
- **Hardware interface**: This sub-criterion describes how easy to access device's hardware, such as camera, GPS, storage and WLAN card.
- **Built-in app interface**: This sub-criterion show how effective to adopt different built-in apps on devices, such as camera, phonebook and photo gallery apps.
- **Web service interaction**: This sub-criterion is to evaluate the ease of using a Web service, such as Google Map, Facebook and IQEngine.
- **User interface builder**: This sub-criterion shows how robust the adopted user interface builder is. A powerful user interface builder will have instantly

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viewable and drag-and-drop capabilities, and other features reducing the workload of developers to create.

Based on several studies (Ekong, 2012; Roy, Rousse, & DeMeritt, 2012; Oz, 2014) done on the subjects taught at universities and colleges, the development of Android-based applications, IOS and Blackberry also emphasizes content such as:

- User Interface Design (multi-touch, basic HCI tenets)
- Storing/Fetching Data (Core Data, SQLite, Content Lists)
- Locating/Sensing (GPS, Cell/WiFi triangulation, participatory sensing)
- Networking (Push Technology, WebKit, Cellular, Wi-Fi, Peer-to-Peer, Bluetooth)
- Graphics/Multimedia (Intro to 2-D, 3-D, Video Streaming)
- Publishing Applications (Getting to the App Stores/Markets)

In addition, this skill is used to develop an application of value-added applications such as producing and maintaining high quality mobile software products. Even developers can gain extensive knowledge in developing applications with the Android SDK.

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5.5 USE CASE DIAGRAM, SEQUENCE DIAGRAM AND ACTIVITY DIAGRAM

During the process of developing an application or prototype running, some diagrams are needed to ensure the flow in progress. This diagram is usually illustrated with easy-to-understand symbols to see the overall application flow. Thus, in the development of the ThreeDLexic the diagrams involved were use case diagrams, sequence diagrams and activity diagrams.

Use case diagrams are usually referred to as behavior diagrams used to describe a set of actions (use cases) that some system or systems (subject) should or can perform in collaboration with one or more external users of the system (actors). Each use case should provide some observable and valuable result to the actors or other stakeholders of the system.

Sequence diagrams describe interactions among classes in terms of an exchange of messages over time. They're also called event diagrams. A sequence diagram is a good way to visualize and validate various runtime scenarios. These can help to predict how a system will behave and to discover responsibilities a class may need to have in the process of modeling a new system.

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Activity diagrams are graphical representations of workflows of stepwise activities and actions with support for choice, iteration and concurrency. In the Unified Modeling Language, activity diagrams are intended to model both computational and organizational processes (workflows). Activity diagrams show the overall flow of control.

5.6 USE CASE DIAGRAM FOR THREEDLEXIC

For ThreeDLexic, use cases are used to describe a sequence of simple steps and interaction between the initiator and the system (Rosenberg & Stephens, 2017). Most of the functional requirements can be explained using the use case diagrams. ThreeDLexic is divided into three main modules, which are Beginner, Intermediate and Advanced.

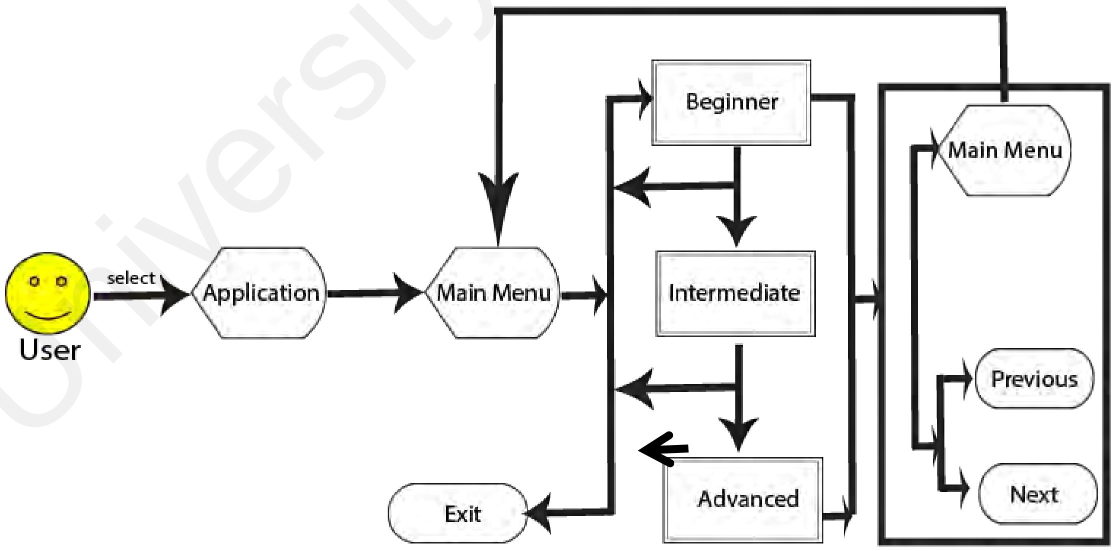

Figure 5.2 : Use Case Diagram for ThreeDLexic

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Use case diagram is used to illustrate the functions of application performed entirely, (Figure 5.2). For the users of ThreeDLexic prototype, they start the operations by selecting application icon, the main menu for the three levels in the lesson section will be displayed. At this stage, only menu for Beginner's lessons, Instructions and Exit button will be functional. This is because the application's system only allows the next level to be accessed after one level is completed. However, users may choose to perform the Exit function at any time.

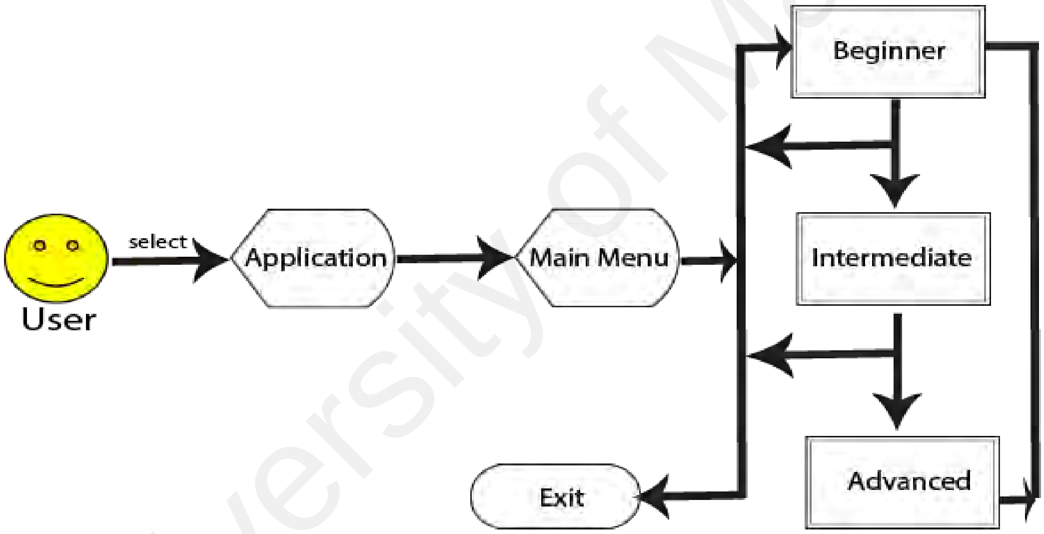

Figure 5.3 : Use Case Diagram for ThreeDLexic Lesson Module

From Figure 5.3, the function of the second use case diagram is to reveal how the users start the prototype where they are allowed to access the lesson menu from the beginner, intermediate and advanced stages, one by one. There are 30 screen pages beginning from 3D letter object which should be completed by users. Skip function is not allowed in this prototype. However users may choose to quit at any time they wish.

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5.7 SEQUENCE DIAGRAM OF LESSON MODULE

This function allows user to select answer based on the question given. This is the stage where user's adapt their knowledge level.

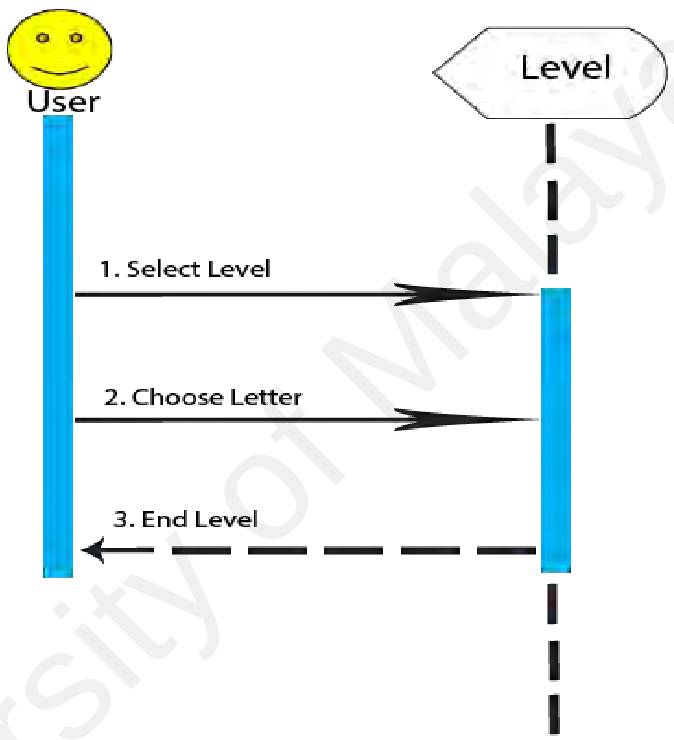

Figure 5.4 : Sequence Diagram of Lesson Module

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Sequence diagram illustrated the sequence of progress for each module in the application as shown in Figure 5.4. This diagram represented three modules for the lesson menu and also three modules for exercise menu. When a user selects a level, he may select the letter he/she wishes to learn. He will continue until he has completed all the ten letters for each level. User may repeat steps 1 to 3 until he/she is familiar with the letter learned.

5.8 ACTIVITY DIAGRAM

The function of the activity diagram is to view the progress of the ThreeDLexic. There are two main activities which are, the level selection and the exercise module.

Figure 5.5 demonstrates the overall control activity at the selection level for selecting the lesson module and exercise module. Command allows the application to exit at any time and users are allowed to return to the main menu before exiting the application.

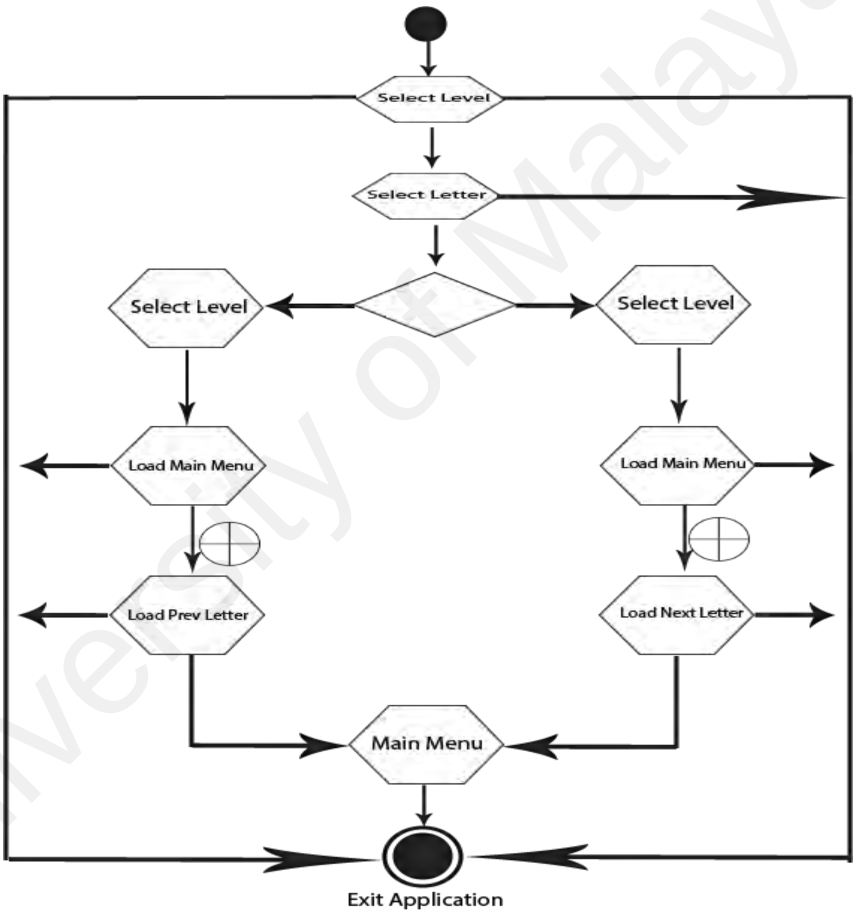

Figure 5.5 : Activity Diagram Of Selecting Level

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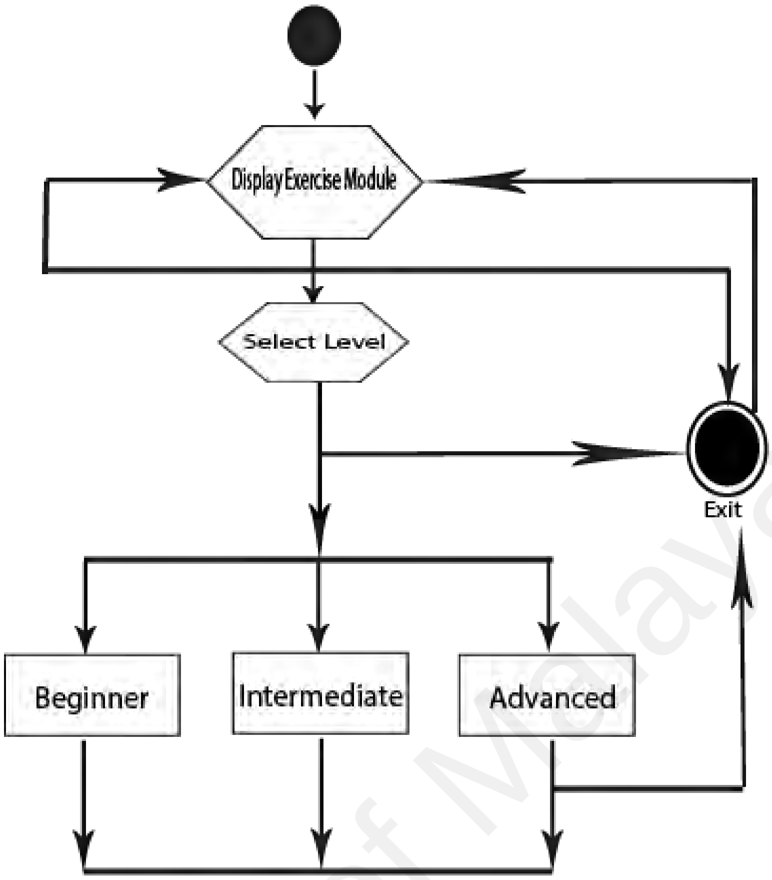

Figure 5.6 : Activity Diagram Of Exercise Module

Figure 5.6 illustrates the activity diagram for the operational navigation in the exercise module for beginner, intermediate and advanced levels. Beginning from the display of the selection menu to each level, users are allowed to exit at any time.

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5.9 NON-FUNCTIONAL HARDWARE AND SOFTWARE REQUIREMENT

Non-functional requirements present a systematic and pragmatic approach to building quality into software systems. Systems must exhibit software quality attributes, such as accuracy, performance, security and modifiability.

In information technology, hardware requirement is the physical aspect of computers, telecommunications, and other devices. The term arose as a way to distinguish the "box" and the electronic circuitry and components of a computer from the program you put in it to make it do things.

The software requirements specification document enlists enough and necessary requirements that are required for the project development. To derive the requirements, the developer needs to have clear and thorough understanding of the products to be developed or being developed. This is achieved and refined with detailed through continuous communications with the project team and customer until the completion of the software.

5.10 NON-FUNCTIONAL REQUIREMENT

i. Performance

Every module available in the ThreeDLexic performed without lagging even though the application uses a 3D environment. Rotational movements for the letters in the 3D

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forms also do not have any problem. Navigations from one level to another level only take two seconds.

ii. Usefulness

ThreeDLexic is capable to assist dyslexic children to write the ten letters which they normally have difficulties doing. Characteristics of the 3 dimensional objects with the 360 degrees rotational capabilities may help them to identify and write better.

iii. Maintainability

The ThreeDLexic can be operated in both android and iOS platform as well as work standalone. For platform such as the Webpage, programmer only need to change the scripts to HTML.

iv. User Friendliness

User-friendliness is a very important issue in whatever application or software developed. As for ThreeDLexic which is developed with the use of Unity3D, it is compatible with all type of tablet operating with the Android systems. Other than that, the 3-dimensional menu displays in this application is very user-friendly to its users who are dyslexic children.

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5.11 HARDWARE AND SOFTWARE REQUIREMENTS

To develop the ThreeDLexic which requires a full 3D environment, the minimum hardware and software specifications required are as illustrated in Table 5.2 and Table 5.3 below:

Table 5.2 : Hardware Requirements to Develop ThreeDLexic Prototype

No.	Hardware	Description
1.	CPU/Operating System	SSE2 instruction set support Windows XP SP2+, 7 SP1+, 8; Mac OS X 10.8+
2.	Memory	64 bit Windows
3.	Hard Disk Space	1 GB
4.	CD/DVD-ROM	HL-DT-ST DVDRAM GT 50N
5.	Monitor	Generic PnP Monitor
6.	Graphic Card	DX9 (shader model 2.0) capabilities
7.	Keyboard	Standard PS 2
8.	Mouse	HID
9.	Speaker	Realtek Digital Output
10.	Tablet	Android: OS 2.3.1 or later; ARMv7 (Cortex) CPU or Atom CPU; OpenGL ES 2.0 or later.

Table 5.3 : Software Requirements to Develop ThreeDLexic Prototype

No.	Requirement	Specifications
1.	Analysis and Design of the prototype	Atlas.ti 7 Microsoft Excel SurveyMonkey
2.	Development of the prototype	Unity4 V4.6.1p4 3D Max Skectup 2015 Adobe Audition CS6
3.	Literature Review	Mendeley Google Scholar UM Lib Interactive
4.	Operating System	Windows 8
5.	Project Planning	Microsoft Project 2010
6.	Report Writing	Microsoft Word 2010 Microsoft Excel 2010 Adobe Ilustrator CS6
7.	Web Player	Web player supports IE, Chrome, Firefox, Safari and others

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5.12 AUTHORING TOOLS

Unity3D is the main authoring tools in the development process of the ThreeDLexic. This game engine-based software possesses the well known 3D elements (Wang et al. 2010) and could be applied on various platforms. This suggestion is agreed by (Kim et al. 2014) because smooth navigation will be acquired with the use of this game engine.

Below is the special characteristics found in the Unity3D game engine (Villacis et al., 2014; Wang et al., 2010):-

i. Multiplatform – the developed prototype may be used on platforms such as Webplayer, PC, Mac & Linux Standalone, Ios, Android, BlackBerry, Window Store, Windows Phone 8, Xbox 360, Xbox Ones, PS3, PS Vita, PS4 and PlayStation Mobile.

ii. Supported Programming Language - JavaScript, C#, and a dialect of Python called Boo.

iii. Cross-Platform Game Development Software - Mac OSX, Unity3D can fully support Windows XP/Vista/7

iv. Can use the underlying .NET libraries which support databases, regular expressions, XML, file access and networking

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5.13 EDITING AND SUPPORTING TOOLS

Editing and supporting tools used in the development of this prototype is the 3D Max for creating the game object, SketchUp 2015 to search for ready made 3D objects and for sound editing, the Adobe software, Audition CS6 was used.

5.14 THE DEVELOPMENT OF THE THREEDLEXIC PROTOTYPE

The structure defines the methods in which users can navigate through the prototype. ThreeDLexic development is an easy process. This is because the prototype will be used by dyslexic children. This development is not loaded with menus that can confuse students. In fact, the use of minimal words has been used. Most interactions in ThreeDLexic consist of dimensionless icons. All the structures of ThreeDLexic are illustrated in Figure 5.7.

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5.15 STRUCTURE OF THREEDLEXIC

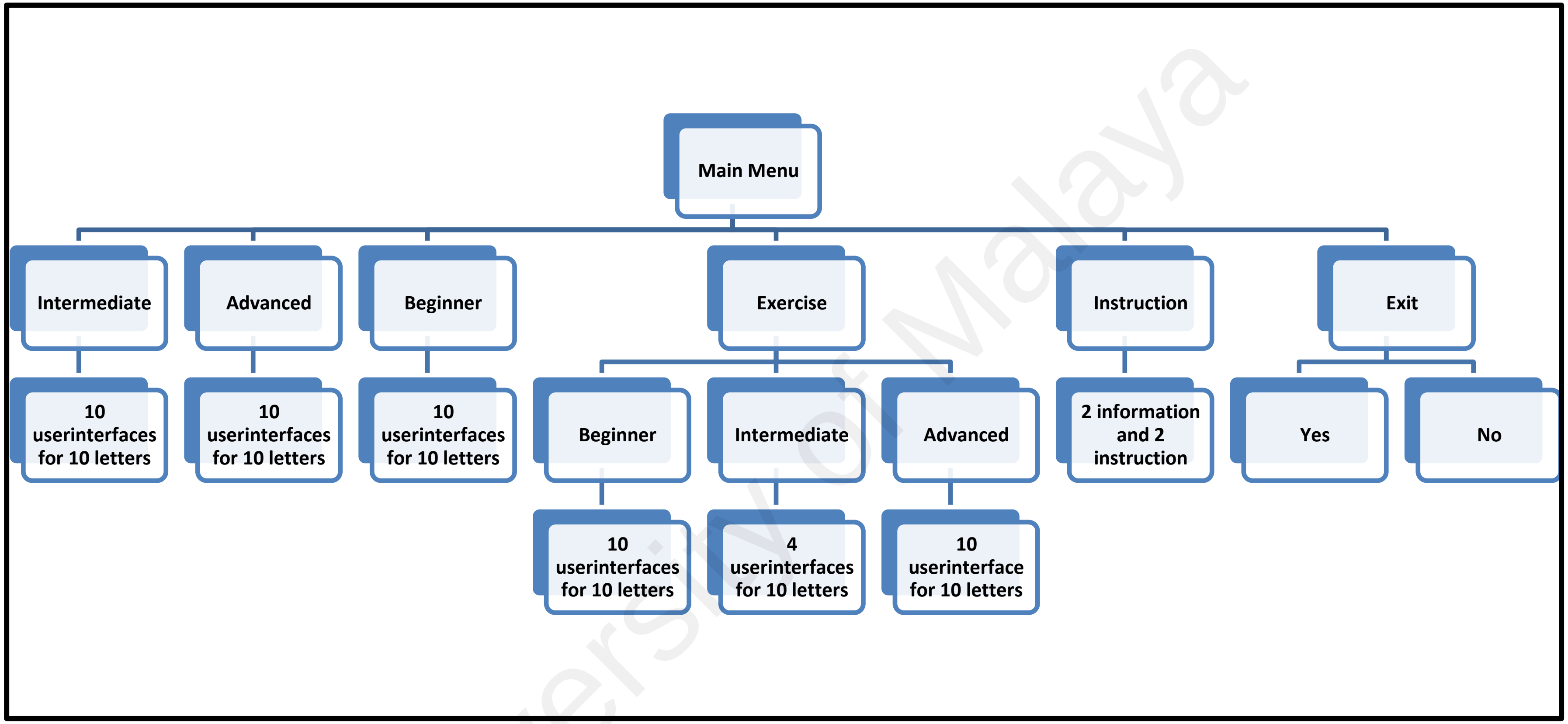

Figure 5.7 : Structure of ThreeDLexic Prototype

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Based on Figure 5.7 above, there were a total of 56 user-interfaces existed. Users may choose to start the prototype by selecting the intermediate menu. Users may start learning the ten letters beginning from the intermediate levels until the advanced levels. Further explanations will be made on the sequence of each menu in the sub-topic of sequence diagram. Besides that, all information and instructions available in the instructions menu are prepared in a voice form.

5.16 PROTOTYPE DESIGN

- Storyboard

It has become a basis in the development of an prototype, that the initial development process should include the storyboard. Story was also designed similar to those in the research by (Aziz, Rasli, & Ramli, 2010; Mara, 2013; Daud & Abas, 2013). For this research, storyboard was analyzed and designed after reviewing data from the first stage, which was the data collection stage (**APPENDIX F**). This is to ensure that the prototype developed will in line with characteristics determined by dyslexic children.

Figure 5.8 : Illustration of Storyboard For Beginner, Intermediate and Advanced Level

- **User Interface**

User interface used in the development of the ThreeDLexic prototype is based on the initial information collected at the beginning of the research. This is highly important to make sure that the prototype fulfilled the criteria appropriate for the dyslexic children. After the completion of the prototype, post-evaluation form were sent to the 10 participating experts. The form was generated using Surveymonkey, an online survey development cloud-based software freely available.

After a few aspects were agreed upon and disagreement was absent, the user interface as shown in Figure 5.9 below was created.

Figure 5.9 : User Interface for Main Menu

The main user interface are designed with 3D objects in the form of mushrooms as the main menu selection options. The key mushroom buttons represent Beginner, Intermediate and Advanced levels. On the other hand, mushroom buttons menu placed on the wall, represents menu option for exercises for beginner, intermediate and advanced levels. And the four smaller mushroom buttons, represent prototype information and instructions in audio mode.

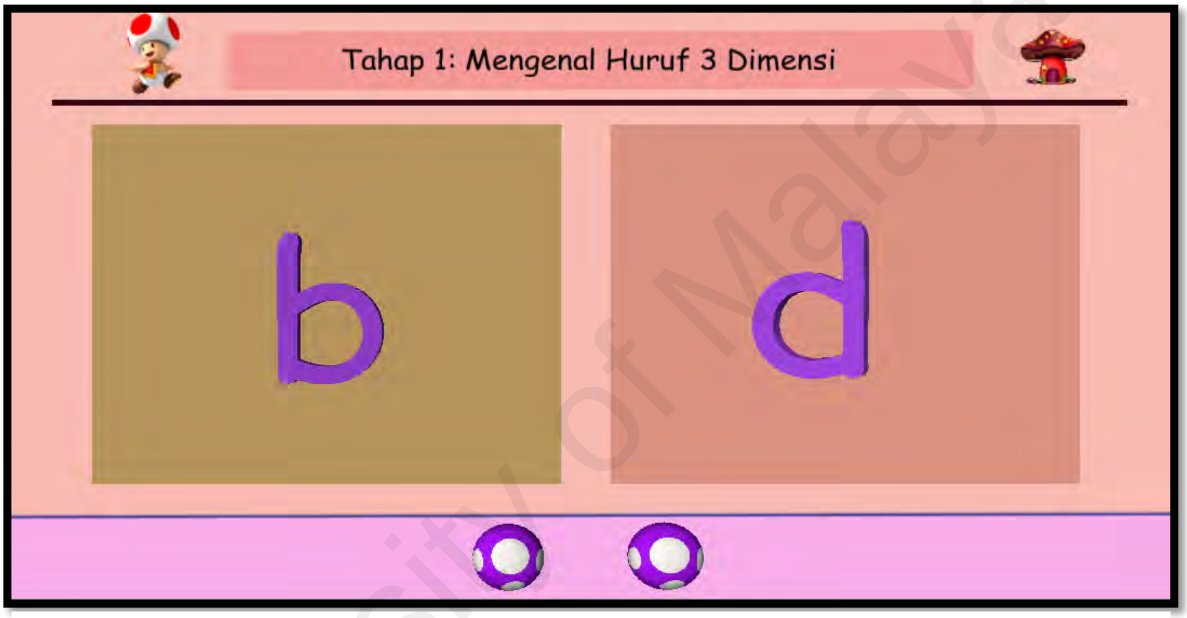

Figure 5.10 : User Interface for Beginner Level

Figure 5.10 above illustrated the interface for beginner level. In this level all the 10 letters involved were in the form of 3D objects. Users may perform rotation of the 3D object in the box on the right. After getting the right letter based on the letter in the box on the left, users may select the mushroom buttons on the right hand side to choose the next letter or the button on the left to return to the previous screen.

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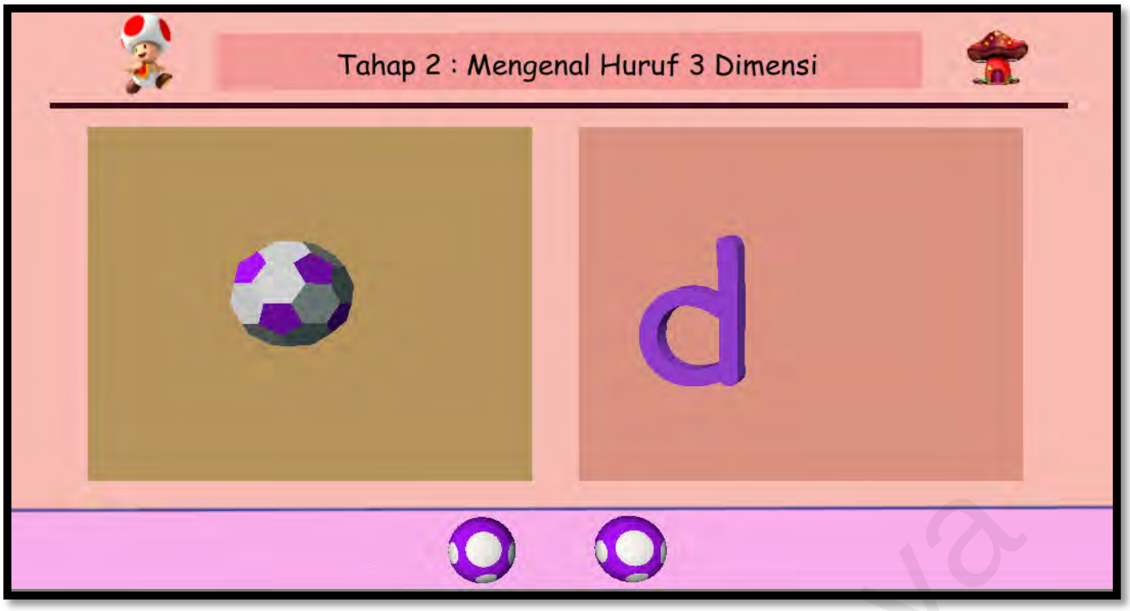

Figure 5.11 : User Interface for Intermediate Level

Figure 5.11 above illustrates the interface for intermediate level. In this level all the ten letters involved are in the form 3D objects. Users may perform rotation on the 3D object in the box on the right hand side. The difference from the screen in the beginner level is users are given a ball as a clue to change the letter to the correct form. After completing the task of changing the letter based on the 3D object (ball), users may select the mushroom buttons on the right to choose the next letter or the button on the left to return to the previous screens.

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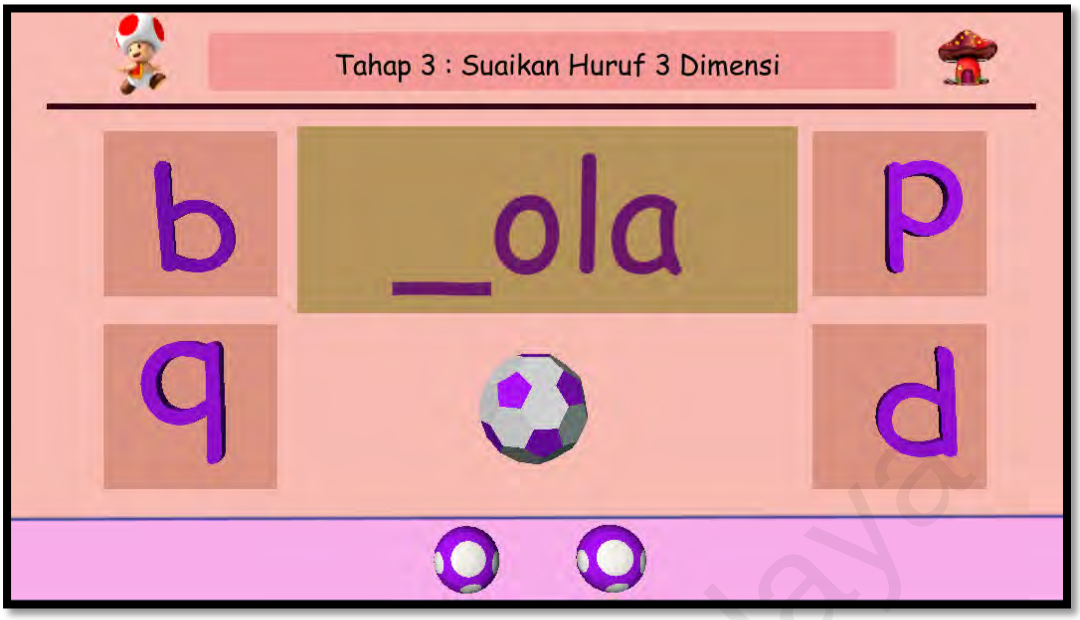

Figure 5.12 : User Interface For Advanced Level

Figure 5.12 above illustrates the interface for advanced level. In this level all the ten letters are also in the form of 3D objects. Users are required to observe a 3D object clue (ball) and select the correct 3D letter and move it to a blank space to form a word. After completing the task of selecting the letter based on the box on the left, users may select the mushroom buttons on the right hand side for next letter or the left button to return to previous screen.

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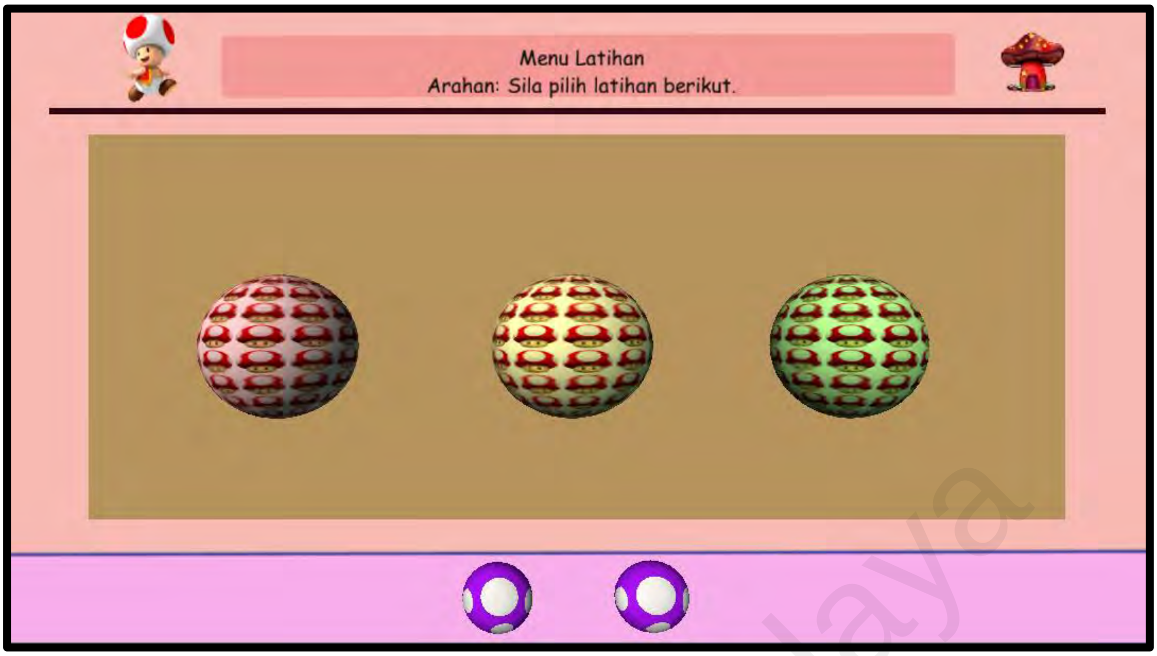

Figure 5.13 : User Interface for Exercise Menu

Figure 5.13 illustrates the interface for exercise menu. There are 3 main menu selection options, which are: red circle representing beginner level, yellow circle representing intermediate level exercise and green circle representing the exercise at the advanced level.

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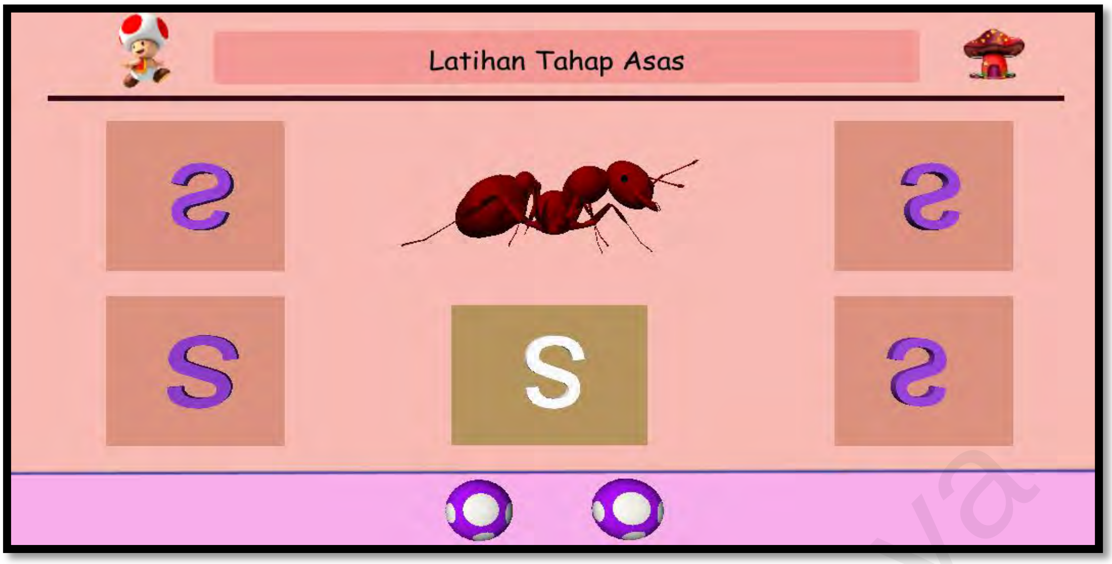

Figure 5.14 : User Interface For Exercise At The Beginner Level

Figure 5.14 above illustrates the interface for an exercise at the beginner's level. In this interface it demonstrates one of the letters in a matching activity with the correct letter. There is an object which functions as a clue to help users in making the right selection. Besides that, the mushroom buttons menu for next and previous screen is also available.

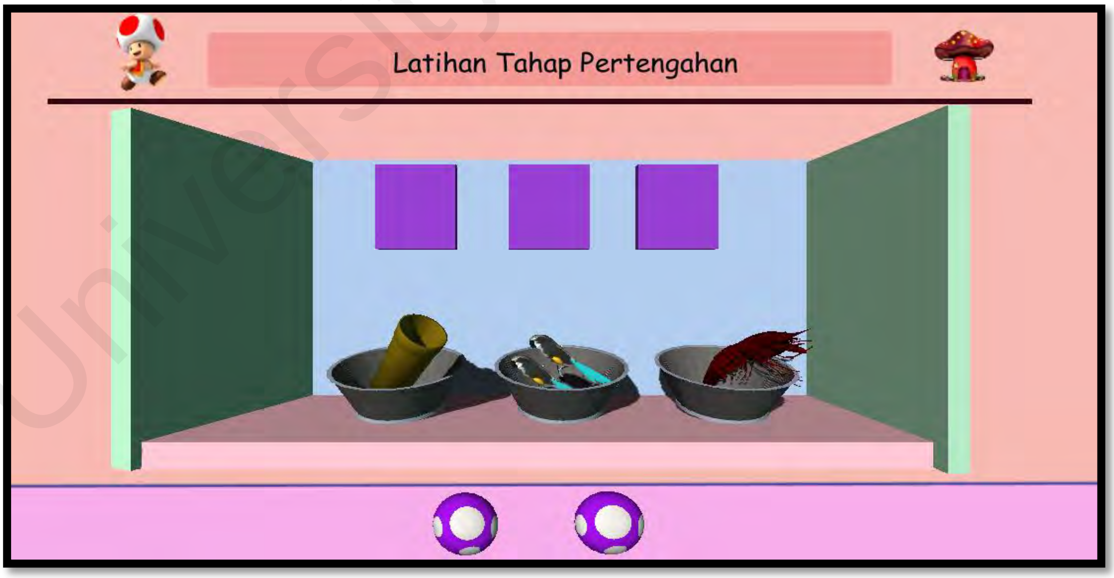

Figure 5.15 : User Interface For Intermediate Level Exercise

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Figure 5.15 above illustrates the interface exercise at the intermediate level. The activity in this interface is to listen to the sound of objects displayed. Users are required to place the first letter of the object correctly. The letters are placed under a purple box. Other than that, the mushroom buttons menu options to navigate to the next and previous screens are also available

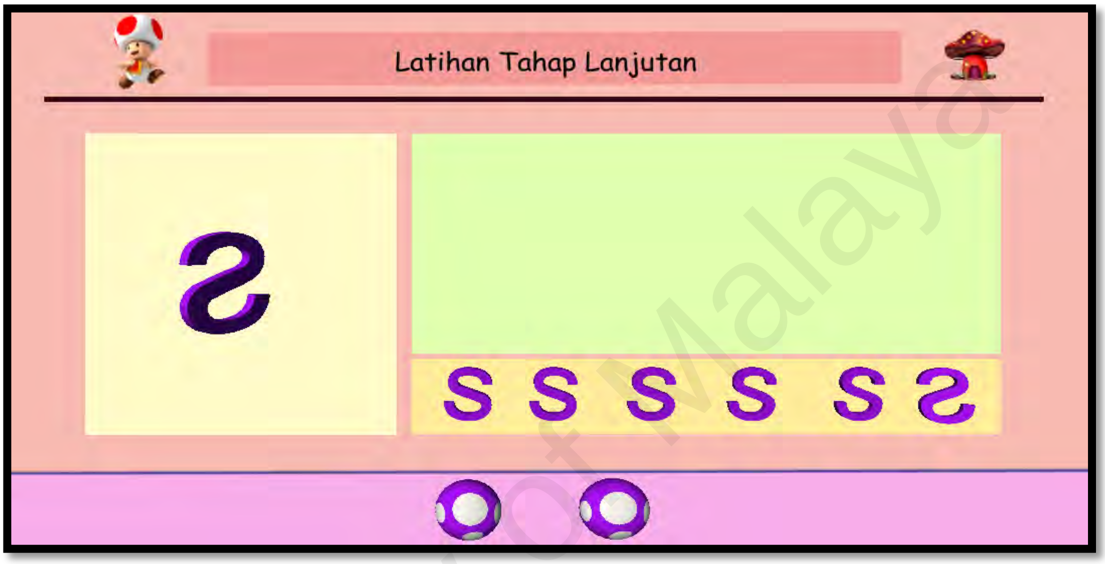

Figure 5.16 : User Interface For Advanced Level Exercise

Figure 5.16 above illustrates the interface for advance level exercise. In this interface the activity prepared is to view the animation of a letter in the box on the left hand side. Users are required to watch attentively until the letter return to its original position and they are encouraged to phonically voice the letter. Besides that, users are required to discard letters that are not in the right position with just a click at the end of the letter. Letters that are in the correct position should be moved to the animation letter, one by one, repeatedly. The purpose is to make sure users are able to identify the actual letter. Again, the mushroom buttons menu options to navigate to the next and previous screens are also provided.

Figure 5.17 : User Interface for Exit Menu

Figure 5.17 above exhibit the interface to exit (quit) from the prototype. Figure 5.17 is a mushroom button at the door indicating the prototype is ready to go to Exit menu selection. If users are in an android tablet environment, they only need to press the "back" button on the gadget and the display will appear. However on a laptop or standalone display, "Escape" key should be pressed as "Yes to restart the prototype and "No" to exit the prototype. Table 5.4 illustrates the elements of multimedia prepared on each display of the ThreeDLexic 3D prototype.

Table 5.5 : Table On Elements Of Multimedia Available On Each Screen Of ThreeDLexic Prototype

Element / Layout Types	Text	Graphic	3D Rotation	Sound	Animation	Video
User Interface For Main Menu	X	✓	✓	✓	X	X
User Interface For Beginner	✓	✓	✓	✓	X	X
User Interface For Intermediate	✓	✓	✓	✓	X	X
User Interface For Advanced	✓	✓	X	✓	X	X
User Interface For Exercise Menu	✓	✓	X	✓	✓	X
User Interface For Beginner Exercise	✓	✓	X	✓	X	X
User Interface For Intermediate Execise	✓	✓	✓	✓	X	X
User Interface For Advanced Exercise	✓	✓	✓	✓	✓	X
User Interface For Exit Menu	✓	✓	X	✓	X	X

All the multimedia elements in the prototype for each screen displays are characteristically minimal. For example, texts are not more than eight words each. The rationale is to ensure dyslexic children to not lose interest when they perceived too many words. According to Rello (2014), length threshold plays an important part in positively encouraging dyslexic children in their learning process. This is because "people with dyslexia encounter problems with very short and very long words". Likewise, the animation element is minimized to avoid confusion in every interface. The implication was corroborated by Manzura (2009) in a research related to

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multisensory for dyslexic children by minimising the element of animation. The video element is not included in ThreeDLexic because the main focus is to examine the role of 3D object while other elements are less important.

- Action Script

Action script used in the ThreeDLexic prototype plays a vital part as one of the essential requirement in the development process. This was to ascertain the efficiency of the prototype as acquiesced by Azizah Jaafar and Chan Siew Lee (2012) in their study to evaluate the usage software usage. Exhibit below illustrated the action script used in selection options menu for options and instructions “next” and “previous”(Appendix I).

5.17 GUIDELINE OF OPTIMAL DELIVERY

- The User Interface

The interface designed must allow users to be able to follow it with the minimum number of use. In this case, the prototype developed is uncomplicated as users may already have experience in using tablets.

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- Redeployment

Unity3D game engine can be applied on various platforms. So there will be no issue for users to use this prototype. Even though, there are differences in screen resolution, the prototype can be operated without any problem.

- Buttons

Buttons available in this prototype is specifically designed based on the needs of users who are dyslexic children. They are able to operate this prototype with ease and without any confusion.

5.18 SETTING UP PHASE

In this implementation phase, we will discuss how the characteristics found in the prototype may be executed on the android platform with the full use of Unity3D software.

Below are the stages to publish created file:

i) Develop the prototype using desktop computer with Unity3D software. Unity3D supported any files used in the prototype.

ii) Determine the needs for setting functionality such as SDK, hardware interface, built-in app interface, web service interaction and user interface builder.

iii) After completing the above, testing must be performed by using file .exe. If there is no problem or error detected, the next step may be performed.

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iv) Main files are ready to be published. File menus are selected and here a few essentials set up such as selecting folder and prototype icon are needed. A dialog box as shown below will be displayed (Figure 5.18).

Figure 5.18 : Dialogue Box for Publish Setting

Next, the device needs to be connected with USB to commence the process of installing with .apk format, for android platform. Finally, the prototype is properly launched.

5.19 SUMMARY

This chapter has explained in detail the processes involved to develop the prototype. Careful thoughts have been considered to ensure that the determination and decision for the end user needs pertaining to the hardware and software aspects fulfilled the research objectives. The next chapter elaborates the evaluation phase.

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CHAPTER 6

RESULT AND DISCUSSION

6.1 OVERVIEW

This chapter discusses the analysis and findings of the evaluation phase of ThreeDLexic, a 3D-animated assistive-reading software for dyslexic children at PDM, an NGO institution based in Kuala Lumpur. Hence, there are two types of data source involved at this stage; the responses from ten experts on the usability of the ThreeDLexic prototype which was analysed using Fuzzy Delphi Method and the observation forms completed by four teachers on four dyslexic children, analysed qualitatively for emerging themes via Atlas.Ti software. All the data collected were triangulated to comprehend the extent to which the prototype helped achieve the objective of letter writing for the dyslexic children.

6.2 PARTICIPANTS

As mentioned in the previous chapters, the analysis phase (pilot study) involved 150 participants of Year 2 and Year 3 pupils' writing document being analysed together with observation on six dyslexic children while using 2D application. While for the evaluation phase, ten experts and four dyslexic children served as the participants. The children were being observed by four trained teachers from PDM's research centre under the training of the researcher. The total number of participants were 170. In the next section, the process of evaluation is elaborated.

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6.3 EVALUATION FROM EXPERTS USING FDM

Analysis using the FDM method involves seven steps until this process results in an agreement between all experts. Ten experts were invited to participate in the evaluation on the usability of ThreeDLexic.

Step 1: Determining Research Topic

In this study, the first step is to determine the subject of the study and the constructs to be measured. The title of the study is 3D Interactive Animation Learning For Dyslexic Children.

Step 2: Determining The Experts

The second step is to determine or to select ten experts for the evaluation. This was performed by sending an instrument to each expert via Surveymonkey. The instrument is attached in Appendix A. The ten experts came from two different fields, which are software design and applications, and pedagogue of dyslexia. Those in the dyslexia pedagogue were four teachers from PDM Ampang and a specialist teacher who had more than 2 years experiences in dyslexia pedagogy. Meanwhile, application experts were, a special education teacher, a lecturer in education technology from Karak Community College, a research assistant from the Faculty of Computer Science and Information Technology of University Malaya and a lecturer from the Faculty of Education, National University of Malaysia. These experts' opinions provided substantive take off in interpreting and determining the robustness of the prototype.

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Step 3: Determining of Fuzzy Scale

The third step is to choose appropriate fuzzy scale. Each response provided by a specialist is calculated using the Fuzzy Delphi Method (FDM) using an excel **(APPENDIX H)** template containing special formulas. The constructs involved are technical (4 items), interface (6 items), multimedia (8 items) and interactivity (6 items). Constructs and items were developed based on suggestions by (Hassan.Johari, 2008) and adapted based on current studies. It should be noted that these modifications were also informed by observations done on six dyslexic children during the analysis phase and implementation stage as discussed in Chapter 3. For example the decision to use the soft color in the prototype is based upon 66.7% agreement by dyslexic children. Subsequently, the items related to color were included in the interface construct to be evaluated by the expert **(APPENDIX C).** This was done in order to ensure that the inclusion of any elements in the design took into consideration the consent of the end users and the experts. In some studies, this part was achieved (Hasan, Hafiz, & Shahril, 2017) they interviewed seven experts and administered a questionnaire which was responded by 21 experts. In the present study, the questionnaire also includes open-ended questions for teachers to voice out their opinions.

In brief, a questionnaire comprising 24 items encapsulated in four sections was developed to gather the experts' view. The questionnaire was adapted from the work of Johari Hassan & Juwairiah Arifin (2008) that focuses on the efficiency of the content and design of a CD ROM on Physics. Even though the CD ROM was not meant for dyslexic children, the questionnaire that was in acquaintance with the CD ROM was selected due to its close similarity in the 3D feature it contains. The items were rated at 1 – 5 Likert scale. This questionnaire was then uploaded to the online survey via 'survey

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monkey' platform and also via emails (**APPENDIX A**). Apart from that, the developed prototype was also uploaded to the dyslexia website**,** www.dyslexia_malaysia.my. Participants were given 35 days to respond to the survey. Their responses were analysed using Fuzzy Delphi Method (FDM) as explained in the succeeding section.

In FDM, the Likert Scale was organized into sub-scale using the following division as depicted in Table 6.1.

Table 6.1 : The Difference Between Likert Scale and Fuzzy Scale for 5 Point

Fuzzy Scale (FDM)			**Scale of Agreement**	**Likert Scale**
0.6	**0.8**	**1**	**Strongly Agreed**	**5**
0.4	**0.6**	**0.8**	**Agree**	**4**
0.2	**0.4**	**0.6**	**Less Disagreed**	**3**
0	**0.2**	**0.4**	**Disagreed**	**2**
0	**0**	**0.2**	**Strongly Disagreed**	**1**

This demonstrated that with the use of Likert Scale, whatever choices made by experts or respondents will only be limited to the given numbers ensuring that the choices are consistent and that its interpretation is direct. For example if a respondent selects 1 in the Likert Scale, the response from respondent or expert will only be interpreted as strongly disagree.

At the same time, for Fuzzy Scale if experts or respondents selected one value from Likert Scale in the form, the interpretations of the selected scale will be translated into three values, which is, the minimum value (m1), the most probable value (m2) and the maximum value (m3). This demonstrated that the interpretations of data into the Fuzzy

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Scale will not be fixed to only one value. This differentiates the robustness of Fuzzy Scale compared to Likert Scale alone.

Step 4 : Getting The Average Value

The fourth step is to get the average value. Every scale given by the experts will be converted to fuzzy scale. The total of fuzzy scale will be divided by 10 experts and will produce an average within the Average Fuzzy Number column as shown in table 4.3 to table 4.7. This first condition is based on a-cut > 0.5 item is acceptable if a-cut <0.5 will not be accepted as a threshold value. The formula below is used:

$$A_{max} = 1/3 * (m_1 + m2 + m3)$$

For this study the value of the five constructs is fulfilled when it exceeds 0.5. This means that the value of the expert agreement is met.

Step 5: Determining The Value Of 'D' (Threshold Value).

Next to qualify the second criteria by determining the value d. Determination of d values such as the formula below:

$$d(\bar{m}, \bar{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]}.$$

Expert agreement has met this requirement as in the schedule 4.3 whereas threshold value d ≤ 0.2 of item is acceptable and if threshold value of item is >0.2 it will not be accepted. Alternatively, a second round of analysis will only take into account the views of experts, which is not in agreement.

Step 6 : Getting A 75% Consensus.

The sixth step is to meet the third requirement based on the Traditional Delphi Method (Chu & Hwang, 2008; Murry & Hammons, 1995) where, percentages of agreement in a group of experts must be > 75%. The trick is to consider items that exceed the value of $d \leq 0.2$. For example, if the multimedia aspect construct had 9 out of 10 scores (1 did not get $d \leq 0.2$) so the score was 90%. For this analysis, the agreement among experts exceeds 75% for each construct.

Step 7 : Get Fuzzy Evaluation And Defuzzified (Score Determining Process)

Fuzzy evaluation is a method for determining the ranking of an item. It is quite a difficult process because it involves complex numbering and an alternative method of using a mathematical formula to determine the ranking. This is called the defuzzified process. Three formula can be used in the defuzzified process to determine ranking/ scoring of the items:

1. Amax = 1/3 * (a1 + am + a2)
2. Amax = 1/4 * (a1 + a2 + 2am)
3. Amax = 1/6 * (4am + a1 + a2)

For this study, the researcher choose formula 1.

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6.4 RESULTS FROM EXPERTS' FEEDBACK USING FDM

Findings from the analysis are illustrated in Table 6.2 to Table 6.6 below:

Table 6.2 is show value of agreement through technical construct. There were four items with ten experts evaluation.

Table 6.2 : Value of Agreement through Technical Construct

Experts	**Items of Technical Aspect**			
	1	**2**	**3**	**4**
1	0.2	0.2	0.2	0.1
2	0.2	0.2	0.2	0.1
3	0.2	0.2	0.2	0.1
4	0.2	0.1	0.2	0.2
5	0.2	0.1	0.2	0.2
6	0.2	0.2	0.2	0.1
7	0.2	0.1	0.2	0.2
8	0.2	0.1	0.2	0.1
9	0.2	0.1	0.2	0.2
10	0.2	0.1	0.2	0.1
Threshold value (d) of each item	0.153	0.147	0.153	0.147
Percentage of each item d ≤ 0.2 (>75%)	100%	100%	100%	100%
Defuzzification (Average Response)	0.70	0.60	0.70	0.66
Defuzzification (Fuzzy Evaluation)	7.00	6.80	7.00	6.60
Ranking elements	**1**	**2**	**1**	**3**

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In Table 6.2, the average value of fuzzy number based on the three conditions was fulfilled. The threshold value (d) of each item is 0.153, 0.147, 0.153 and 0.147 for item 1 to 4 respectively. All items received total agreement by experts (100%). Value of a-cut 0.5 is 0.70, 0.60, 0.70 and 0.66 for item 1, 2, 3 and 4 respectively. This means that items in the technical construct is highly and unanimously accepted among the experts.

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Table 6.3 shows the value of agreement for the interface construct with six items evaluated by ten experts.

Table 6.3 : Value of Agreement through Interface Construct

Experts	Items of **Interface** Aspect					
	1	**2**	**3**	**4**	**5**	**6**
1	0.2	0.2	0.2	0.2	0.2	0.2
2	0.1	0.1	0.2	0.2	0.2	0.1
3	0.2	0.1	0.4	0.1	0.2	0.1
4	0.1	0.4	0.4	0.1	0.2	0.1
5	0.1	0.2	0.1	0.1	0.1	0.1
6	0.2	0.1	0.1	0.1	0.1	0.2
7	0.1	0.1	0.2	0.1	0.1	0.1
8	0.1	0.2	0.2	0.2	0.2	0.2
9	0.1	0.1	0.2	0.1	0.1	0.2
10	0.1	0.1	0.1	0.1	0.1	0.1
Threshold value (d) of each item	0.128	0.147	0.214	0.128	0.147	0.142
Percentage of each item d ≤ 0.2 (>75%)	100%	90%	80%	100%	100%	100%
Defuzzification (Average Response)	0.66	0.64	0.66	0.66	0.68	0.70
Defuzzification (Fuzzy Evaluation)	6.66	6.40	6.66	6.66	6.80	7.00
Ranking elements	3	4	3	3	2	1

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While in Table 6.3, the average value of fuzzy number based on the three conditions was also fulfilled. For item 1, threshold value (d) of each item is 0.128, item 2 is 0.147, but for item 3 is 0.214, item 4 is 0.128, item 5 is 0.147 and item 6 is 0.142. Items 1, 3, 4 and 5 has agreement of 100%. While for item 2 and 3, 90% and 80% agreement were recorded respectively. Value of a-cut 0.5 is 0.66, 0.64, 0.66, 0.66, 0.68 and 0.7 for item 1, 2, 3, 4, 5 and 6 respectively. This means that items in the interface construct is acceptable in the experts' view.

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Table 6.4 shows the agreement for multimedia construct. There were eight items evaluated by the experts.

Table 6.4 : Value of Agreement through Multimedia Construct

Experts	Items of **Multimedia** Aspect							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.0
2	0.1	0.0	0.2	0.2	0.1	0.2	0.2	0.0
3	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.0
4	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.0
5	0.2	0.0	0.1	0.2	0.1	0.2	0.2	0.0
6	0.2	0.0	0.2	0.2	0.1	0.2	0.2	0.0
7	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.3
8	0.1	0.3	0.2	0.2	0.1	0.2	0.2	0.1
9	0.1	0.0	0.2	0.5	0.5	0.4	0.4	0.1
10	0.1	0.0	0.1	0.2	0.1	0.2	0.2	0.4
Threshold value (d) of each item	0.128	0.061	0.153	0.191	0.191	0.183	0.180	0.089
Percentage of each item d ≤ 0.2 (>75%)	100%	80%	100%	90%	90%	90%	90%	80%
Defuzzification (Average Response)	0.66	0.60	0.67	0.70	0.68	0.58	0.64	0.74
Defuzzification (Fuzzy Evaluation)	6.60	6.00	6.73	7.06	6.80	5.80	6.40	7.40
Ranking elements	5	6	4	2	3	8	7	1

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Table 6.4 shows that the average value of fuzzy number based on the three conditions was fulfilled. For item 1, threshold value (d) is 0.128, 0.061, 0.153, 0.191, 0.19, 0.183, 0.180 and 0.089 for item 1 to 8 respectively.

In terms of agreement, item 1 and 2 reported 100%. While the total agreement for items 4, 5, 6 and 7 is 90% while for items 2 and 8, the agreement is 80%. Value of a-cut 0.5 is 0.66, 0.60, 0.67, 0.70, 0.68, 0.58, 0.64 and 0.74 for item 1, 2, 3, 4, 5, 6,7 and 8 respectively. This means that items in the multimedia construct is unanimously accepted by the experts.

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Table 6.5 shows value of agreement for teaching and interactivity construct. There were 6 items evaluated by the experts.

Table 6.5 : Value of Agreement through Teaching and Interactivity Construct

Experts	**Items of Multimedia Aspect**					
	1	**2**	**3**	**4**	**5**	**6**
1	0.1	0.1	0.2	0.2	0.1	0.1
2	0.2	0.2	0.2	0.1	0.1	0.1
3	0.1	0.1	0.4	0.1	0.2	0.2
4	0.1	0.1	0.1	0.1	0.2	0.2
5	0.2	0.2	0.2	0.2	0.1	0.1
6	0.2	0.2	0.1	0.2	0.1	0.1
7	0.1	0.1	0.1	0.1	0.2	0.2
8	0.1	0.4	0.1	0.1	0.1	0.1
9	0.1	0.1	0.1	0.1	0.2	0.2
10	0.1	0.1	0.1	0.2	0.1	0.1
Threshold value (d) of each item	0.128	0.147	0.147	0.147	0.147	0.148
Percentage of each item d ≤ 0.2 (>75%)	100%	90%	90%	100%	100%	100%
Defuzzification (Average Response)	0.66	0.64	0.64	0.68	0.72	0.64
Defuzzification (Fuzzy Evaluation)	6.60	6.40	6.40	6.80	7.20	6.40
Ranking elements	3	2	2	2	1	2

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As shown in Table 6.5, the average value of fuzzy number based on the three conditions was fulfilled. The threshold value (d) for item 1 is 0.128, while for items 2, 3, 4 and 5 is 0.147 and for item 6 is 0.148. The agreement reported for items 1, 4, 5 and 6 is 100%. While for item 2 and 3 the agreement reported is 90%. Value of a-cut 0.5 is 0.66, 0.64, 0.64, 0.68, 0.72 and 0.64 for item 1, 2, 3, 4, 5 and 6 respectively. This means that items in the interface construct are unanimously accepted by the experts.

Throughout the analysis, it can be summed up that all the four aspects in this instrument achieved collective approval by experts entailing its effectiveness in assisting dyslexic children to at least minimize the reversal letter writing cases.

Table 6.6 : Fuzzy Delphi Method (FDM) Results from Expert Consensus

Conditions	**Aspects / Constructs**				
	Technical	Interface	Multimedia	Interactivity	Total
Number Of Item	4	6	8	6	24
Threshold value (d) of each Construct	0.15	0.15	0.15	0.14	0.15
Percentage of each item d ≤ 0.2 (>75%)	100%	100%	93%	97%	97.5%
Defuzzification (Average Response)	0.69	0.67	0.66	0.64	0.67
Defuzzification (Fuzzy Evaluation)	6.65	6.67	6.60	6.43	6.58
Ranking elements	2	1	3	4	3

Based on the results tabulated in Table 6.6, all the three conditions for both the technical and interface aspects were fulfilled. In particular, both portray the threshold value (d) of 0.15, the agreement reported is 100% and the a-cut value the defuzzification is > 5 is 0.67.

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6.5 EVALUATION FROM TEACHERS

As mentioned earlier in Chapter 4, there were four teachers involved as the inter-rater during the observation process on four dyslexic children using the ThreeDLexic application. The researcher was also present during the observation. The teachers were trained prior to the task whereby they were given a sample of video to observe. Their responses had been moderated to ensure consistency. After a few series of training and consistency was gradually achieved, they were asked to observe the children using the prototype for a consecutive 14 days. They were given a two-month time frame to complete the task.

To collect the data from the teachers while they observed the children using the prototype, a form was created as depicted in Appendix B. It consists of five open-ended items whereby teachers needed to fill in upon their observation on the following aspects: how the children choose the 3D menu (ie. confused, confident), how children rotate the 3D alphabets, how they match the 3D alphabets. Apart from that, teachers also were asked to gauge the suitability of the layout of the prototype ie the arrangement, brightness and the colour scheme by filling in the space provided in the same form. The five predetermined themes / labels analysed from the video are explained in table 6.7 below:

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Table 6.7 : Five Predetermined Themes

Theme/Label	Definition	How it is measured/observed
Element layout	The way the objects are arranged, the colour and brightness of the objects that made children easy to select, and that help children to respond better to the instructions in the prototype.	Does the arrangement allow children to select objects easily or distracting the chidren's focus? Does the colour and brightness used help children to respond better to teacher's instructions or distracting the children to focus?
Menu chosen	The easiness of the three menus to be chosen by the children. Whether they can make the choice on the menu with or without the help or the guide from the teachers.	Does the menu selected with or without teacher's help?
3D rotation	Pupils make spin on 3d letter objects either smooth or difficult.	Does the 3D rotation smoothly and accurate during the rotated.
Letter matches	Involves the movement of 3D letter objects to match the existing letters.	Does the 3D letter objects can suit properly with the existing letters?
Animation feedback	Involves the reaction of the students whether they can help students understand the instructions given if giving instructions in the form of animation	Does the animation helped the pupils to understand the instruction?

To ease the task of observation, each teacher was assigned to a particular participant to be observed during the time frame of two months. The following of task distribution is used:

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Table 6.8 : Coding Subject in Atlas.Ti (As using in Figure 6.2)

Teachers	Pupils Pseudo Name
RQ6 Teacher_Lakshanika	RQ16 Hannah_Student1
RQ7 Teacher_Soraya	RQ17 Nik Aidan_Student1
RQ8 Teacher_Hasnor	RQ14 Aqiff_Student1
RQ9 Teacher_Aini	RQ15 Damia_Student1

To aid readability on the evidences produced, a coding was assigned to each piece of evidence and participant before they were subjected to AtlasTi. Each piece was assigned with prefix RQ followed by a number, which depicts the number of evidence produced in sequence through out the analysis. For example, RQ6 is a sixth evidence produced when an observation took place.

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Table 6.9 : Subject Coding for Atlas. Ti Qualitative Analysis for ThreeDLexic Teacher Observe (As using in Figures 4.17,4.20,4.22)

Subject Coding for Atlis.Ti	Subject /Pseudo Name	Subject Coding for Atlis.Ti	Subject /Pseudo Name
RQ1	Element Layout	RQ39	Letter_d1
RQ2	3D Menu Choosen	RQ40	Letter_n
RQ3	3D Rotation	RQ41	Nikaidan_Student_ThreeDLexic
RQ4	3D Letter Matches	RQ42	Letter_u
RQ5	3D Animation Feedback	RQ43	Letter_s
RQ6	Teacher_Lakshanika	RQ44	Letter_v1
RQ7	Teacher_Soraya	RQ36	Letter_v
RQ8	Teacher_Hasnor	RQ37	Letter_p
RQ9	Teacher_Aini	RQ38	Letter_b1
RQ10	ThreeDLexic		
RQ11	Mylexic		
RQ12	Focus Group		
RQ13	Control Group		
RQ14	Aqiff_Student1_MyLexic		
RQ15	Damia_Student2_MyLexic		
RQ16	Hannah_Student1_ThreeDLexic		
RQ17	Nik Aidan_Student_ThreeDLexic		
RQ18	Day_1		
RQ19	Day_2		
RQ20	Day_3		
RQ21	Day_4		
RQ22	Day_5		
RQ23	Day_6		
RQ24	Day_7		
RQ25	Day_8		
RQ26	Day_9		
RQ27	Day_10		
RQ28	Day_11		
RQ29	Day_12		
RQ30	Day_13		
RQ31	Day_14		
RQ32	Letter_b		
RQ33	Letter_b		
RQ34	Letter_z		
RQ35	Letter_z1		

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Table 6.10 : Subject Coding for Atlas. Ti Qualitative Analysis for Multimedia Measurements File (As Using in Figures 4.15,4.16)

Subject Coding for Atlis.Ti	Subject /Pseudo Name
RQ1	Types Of Instruction
RQ2	Types Of Colour
RQ3	Types Of Level
RQ4	Multimedia Elements
RQ5	Easy Instruction
RQ6	Medium Instruction
RQ7	Hard Instruction
RQ8	Soft Colour
RQ9	Bright Colour
RQ10	Beginner_Level
RQ11	Intermediate_Level
RQ12	Advanced_Level
RQ13	Student 1
RQ14	Student 2
RQ15	Student 3
RQ16	Student 4
RQ17	Student 5
RQ18	Student 6
RQ19	Text
RQ20	Graphics
RQ21	Video
RQ22	Video (Canceled)
RQ23	Animation
RQ24	Voice/Sound
RQ25	Feedback
RQ26	Reaction

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Table 6.11 : Subject Coding for Atlas. Ti Qualitative Analysis for ThreeDLexicvsMyLexic's File (Figures4.19,4.20)

Subject Coding for Atlis.Ti	Subject /Pseudo Name
RQ1	Participant_1 Crystal
RQ2	Participant_2 Aqif
RQ3	Participant_3 Arissa
RQ4	Participant_4 Iman
RQ5	Most Fun
RQ6	Best Learning
RQ7	Easiest To Use
RQ8	Teacher Would Choose
RQ9	I Would Choose
RQ10	MyLexic 2 Dimension
RQ11	NA
RQ12	Strongly Disagree
RQ13	Disagree
RQ14	Less Disagree
RQ15	Agree
RQ16	Strongly Agree
RQ17	First Choice
RQ18	Second Choice

6.6 THE ANALYSIS ON TEACHERS' EVALUATION

There are three types of analysis done on the single source of data gathered. In other words, triangulation is executed to ensure robust analysis in yielding rich ad thick findings. As mentioned in Chapter 3, the mixed method design of this study allows synthesis and triangulation among multiple sources of information. Multiple types of methods profoundly accepted as strengthening the quality and credibility of the evidentiary support for findings and recommendations, especially in complex interventions where any single data source will have inherent limitations.

In this study, once the observation was recorded, their responses were subjected to AtlasTi. The objective for this evaluation is to determine the extent to which the 3D

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elements help improve letter writing of dyslexic children. In particular, its ultimate goal is to see the improvement made in letter writing while using the 3D features as opposed to 2D features. The results of the analysis is depicted in Figure 6.1 and Figure 6.2 .

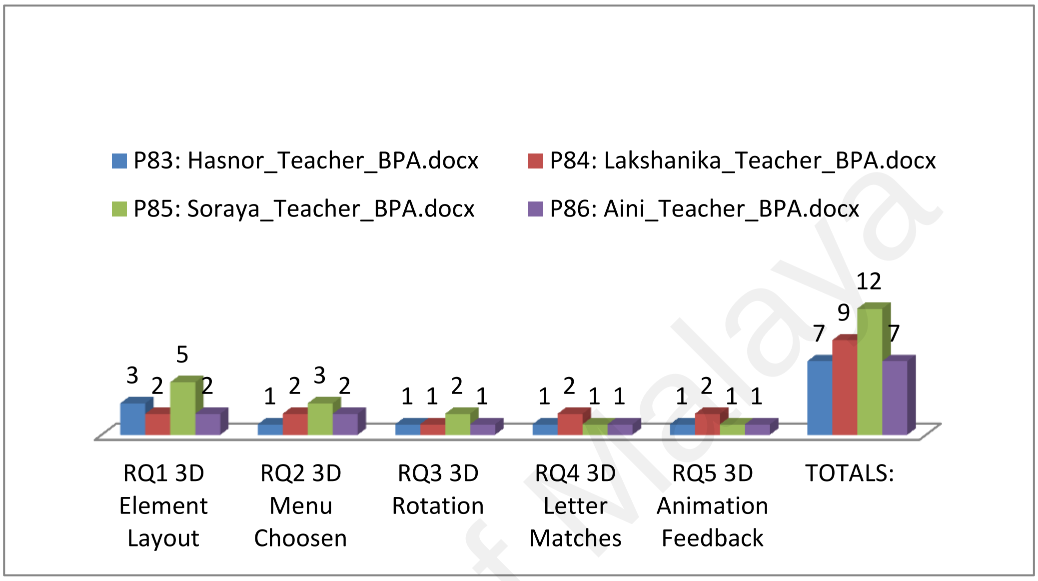

Figure 6.1 : Graph Showing Themes emerged from 3D analysis based on Teachers Observations

Analysis was done by quantifying the positive comments given by each teacher with regards to five aspects determined earlier (i.e layout, menu, rotation, letter matching, reaction towards 3D animation) which were asked in the form (appendix B). These five aspects were the predetermined themes that were suggested by the literature. Responses from four teachers were subjected to qualitative analysis via Atlas.Ti software. Phrases or words that represent and reflect the positive aspects are exemplified by: 'display is clear' 'cool colours used' (layout); 'easy to choose' (menu); 'student can imitate the movement confidently' (rotation); 'student can do without the help of teacher' (letter match); 'students are focused…' (i.e reaction towards 3D animation). Apart from the positive feedback from teachers, negative phrases were also reported. These are exemplified by phrases such as 'somewhat difficult' (letter match), 'still need teacher's guidance' (reaction towards 3D animation). These phrases were mapped onto the five

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predetermined categories or themes to gauge the extent to which the prototype namely the ThreeDLexic achieved the objectives of its design.

As depicted by Figure 6.2, positive reactions were obviously recorded. Based on the descending number of comments received, Teacher Soraya (P85) recorded 12 comments, Teacher Lakshanika (P84) recorded 9 comments, Teacher Hasnor (P83) and Teacher Aini (P86) recorded 7 comments each. Scrutinising the results, with regards to the 3D Element Layout, the comments paved to a conclusion that students were more focused in their learning while using the 3D prototype due to the animation-embedded objects that attracted the attention of these children to stay focused.

Apart from that, according to the teachers, the colour combinations used in the prototype were suitable for dyslexic children. This is in line with the findings in sub-topic 5.3.2 which indicated that dyslexic children preferred soft colours as opposed to bright colours. While for 3D Chosen Menu, the teachers mentioned that the use of 3D objects in the selection menu did not confuse the dyslexic children, in fact the 3D objects were easy to choose, highly interactive, posed no interruptions to students' focus and furthermore, students were fascinated with the menu display in 3D. For 3D rotation element, teachers unanimously voiced out that dyslexic children were able to perform rotational direction of the letters in 3D accurately as the example provided. Apart from that, they also believed that students were more focused in performing activities that involved rotations, however, they suggested that such rotation activity required persistency from dyslexic children.

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Findings from 3D-letters matching activity, teachers concurred that dyslexic children were very fascinated with this activity but needed guidance from their teachers as they faced difficulties in identifying the actual letters. For 3D animation, teachers agreed that dyslexic children learned quicker in sounding letters phonically. They were attracted to the 3D animation letter, and it was easier for them to follow this activity. However, this activity needs teachers' guidance.

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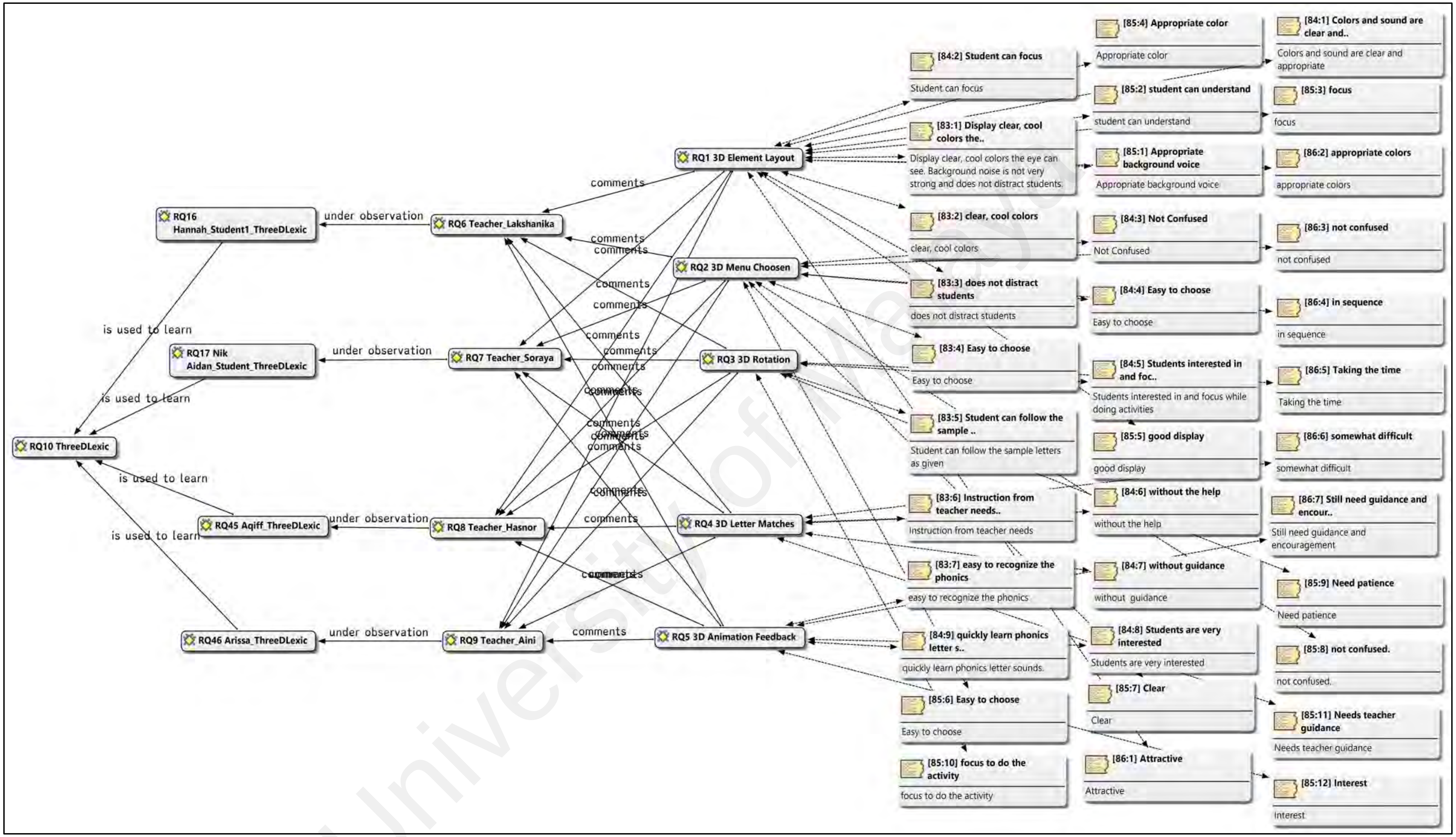

Figure 6.2 : Diagram Showing Themes emerged from 3D analysis based on Teachers Observations

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6.7 ANALYSIS ON DYSLEXIC CHILDREN'S RESPONSES

In this section onwards, further analysis on the students' behavior recorded via video is elaborated. Drawing from the teachers' opinion collected in the form, video was further analysed to triangulate the findings. For this purpose, there are two steps involved: episodes from the video that mapped onto the five constructs were carefully clipped into Atlas.Ti, before transferring the results obtained from the Atlas.Ti into excel to calculate the frequency.

Apart form that, to ensure a robust analysis, three perspectives of analysis were done: based on behavior's comparison while using 2D and 3D, based on progress made on specific letters each day over the two months' period of observation, and based on individual achievements on specific letter.

6.7.1 COMPARISON BETWEEN BEHAVIOR ON 2D AND 3D PROTOTYPE

The objective of this analysis was to make comparison in the behavior of the children while using both 2D and 3D prototypes. The behaviors of four dyslexic children were observed while they were using 3D after they used the 2D application.

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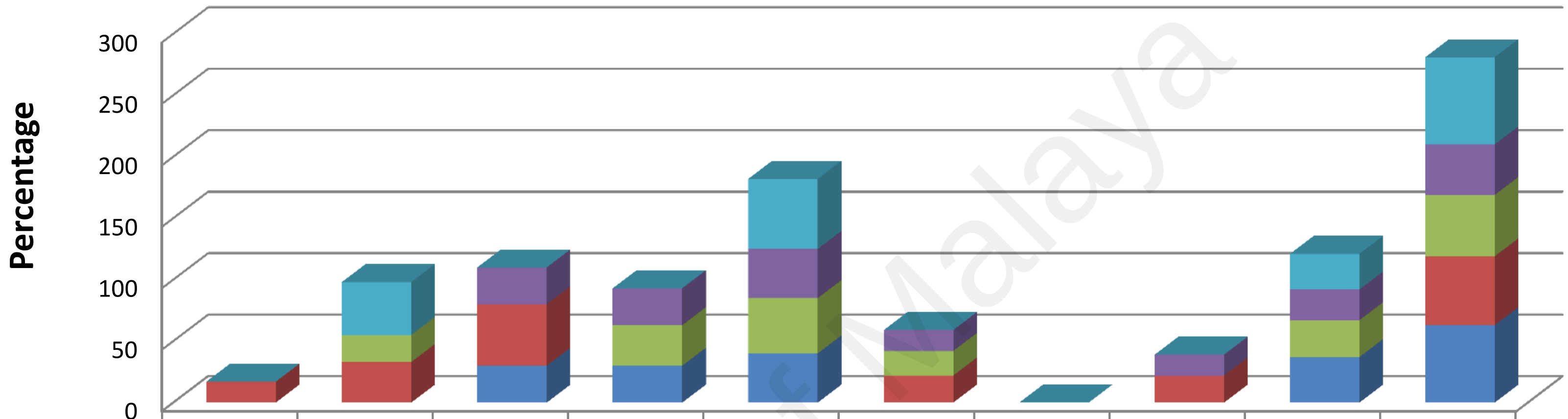

	2 Dimension Application					3 Dimension Application				
	Strongly Disagreed	Disagreed	Less Disagreed	agreed	Strongly agreed	Strongly Disagreed	Disagreed	Less Disagreed	agreed	Strongly agreed
I Would Choose	0	43	0	0	57	0	0	0	29	71
Teacher Would Choose	0	0	30	30	40	17	0	17	25	41
Easiest To Use	0	22	0	33	45	20	0	0	30	50
Best Learning	17	33	50	0	0	22	0	22	0	56
Most Fun	0	0	30	30	40	0	0	0	37	63

Figure 6.3 : Comparison Between Behavior On 2D and 3D Application

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After they had tried both applications, the researcher interviewed them separately. A form with five items assisted the interview, a smiley meter was used as the rating scale (**APPENDIX F**). The smiley meter ranged as ‘strongly disagree, disagree, less agree, agree, strongly agree’. The interview was aimed at gathering the participants’ perceptions with regards to the 2D and 3D characteristics. The items asked are:

Figure 6.4 : Interface Between these two applications (2D below and 3D above)

1. Which is more fun?
2. Which has better learning experience?
3. Which is easier to use?
4. Which one my teacher would choose?
5. Which is more preferred by me?

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The result of the analysis is tabulated in Table 6.3. Only selection for strongly agree is focused since it gives more distinctive insights on the favourable selection between the 2D and 3D. It is found that 63% of the participants strongly agree that 3D is 'more fun' as opposed to 2D application (40%). This entails that 3D is more favoured by the participants. Similarly, 3D recorded highest frequency of agreement (56%) for 'the better learning experience' defeating the 2D application. For 'easier to use', 55% agreement was recorded for 3D while another 45% strongly agree for 2D application. These results suggest that the dyslexic children are more comfortable with the 3D prototype. For the next criteria i.e "teachers would choose", most students picked 40% for 2D and 41% for 3D. This established that students favour if their teachers choose 3D prototype. For "preferrable application", the 3D application is reported to have 71% agreement as opposed to 2D application 57%. The raw data is shown in **APPENDIX F** and **APPENDIX G**.

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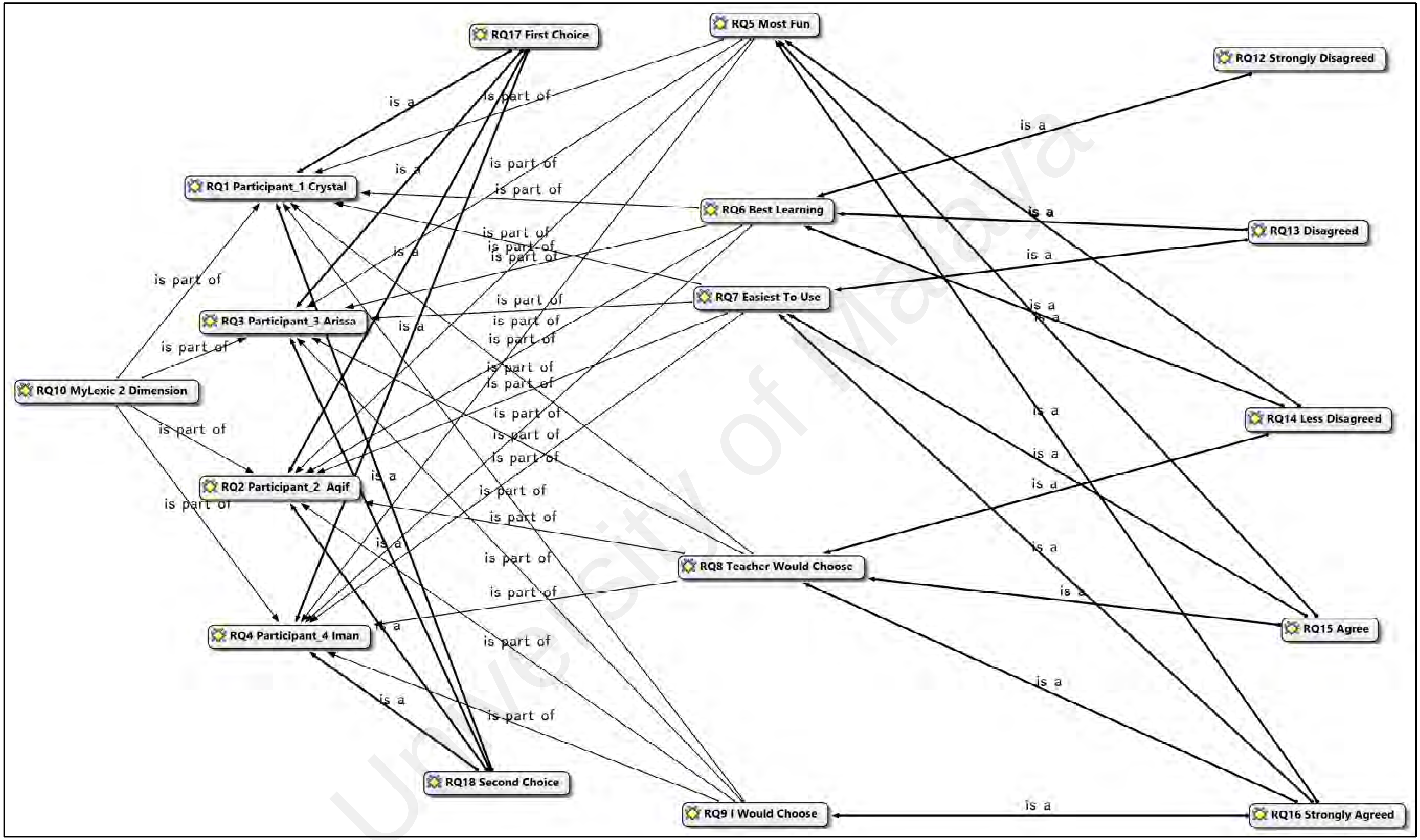

Figure 6.5 : Diagram Comments And Response From Dyslexic children On The 3D Application

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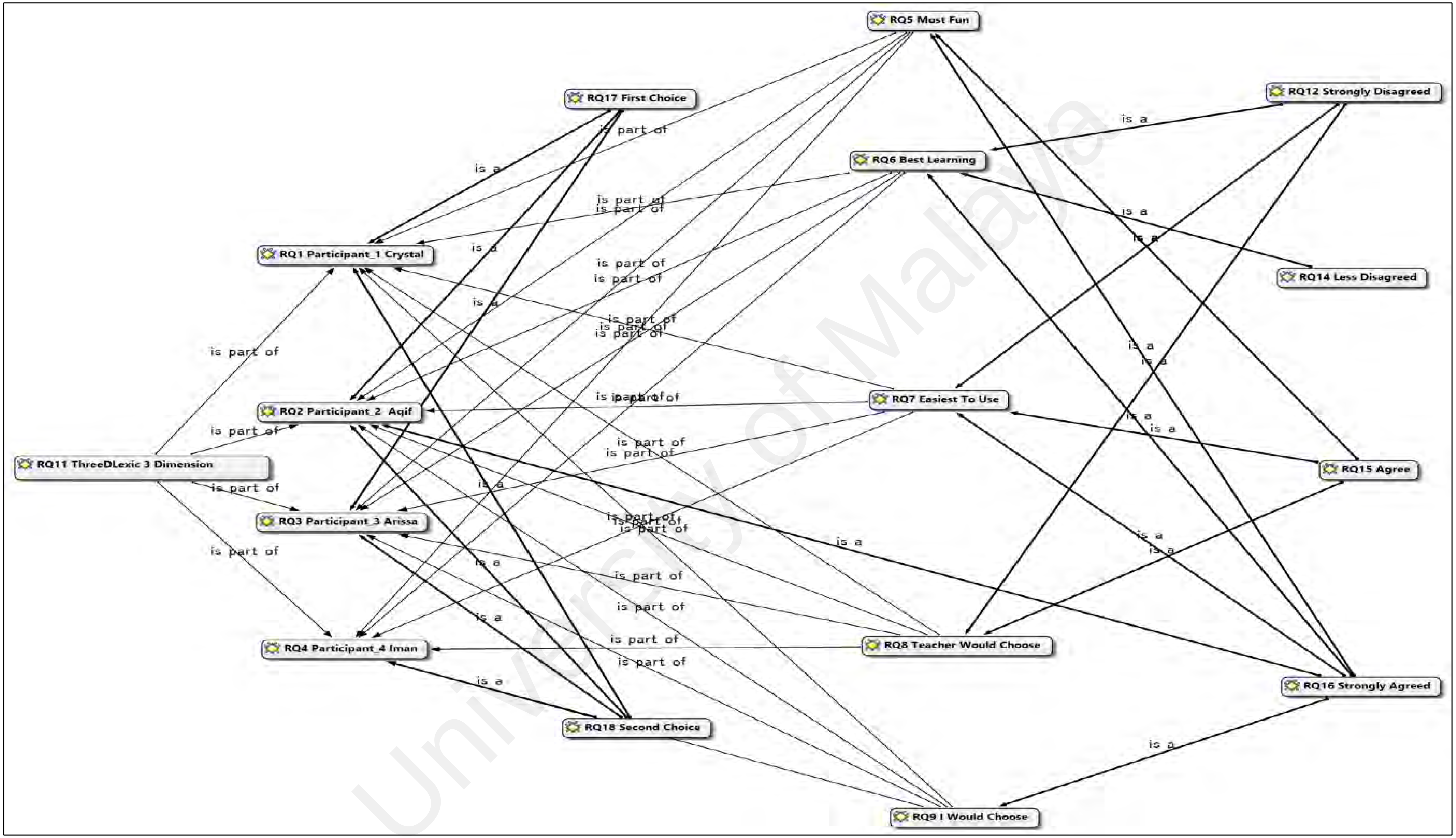

Figure 6.7 : Diagram Comments And Response From Dyslexic children On The 3D Application

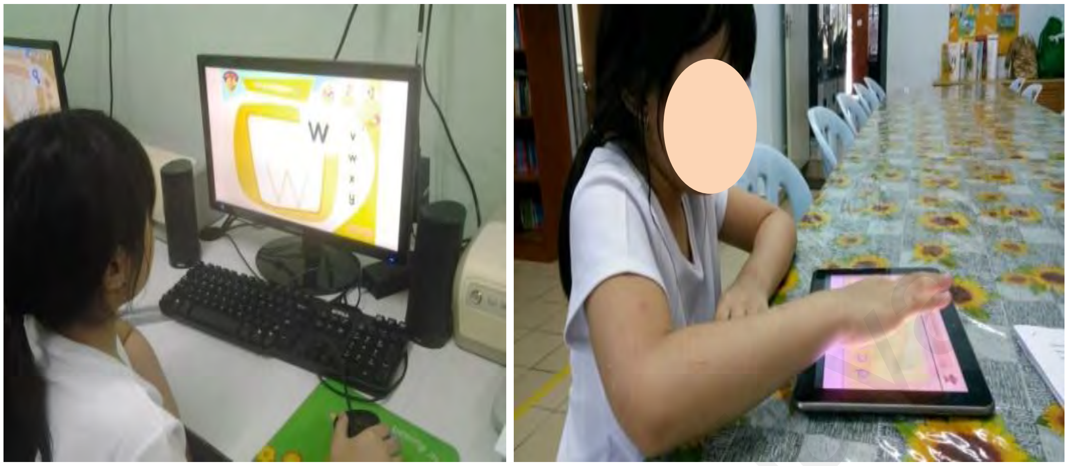

Figure 6.8 : A Dyslexic Pupil Is Using Both The 2D And 3D Applications Before Being Interviewed By Researcher

6.7.2 ANALYSIS ON THE LETTER WRITING DEVELOPMENT BASED ON PROGRESSIVE DAYS

Apart from comparing the 2D and 3D prototypes, the data was also analysed to see any progress on each letter achieved within two months of using both applications. Building cumulatively from the previous findings, careful scrutiny was again done on the recordings to observe and analyse any progress made on the letters according to the day, starting from Day 1 until Day 14. Those letters were ‘b’, ‘d’, ‘m’, ‘n’, ‘p’, ‘s’, ‘u’, ‘v’, ‘w’ and ‘z’. The time taken to write each letter correctly or when the improvement was detected was observed. All 14 days of data is recorded using the 2D and 3D Prototype Monitoring Forms (**APPENDIX D**). A total of 483 letters have been written by students. The episodes from the video was analysed using Atlas.Ti. Analysis generated from both groups are shown in Figure 6.9.

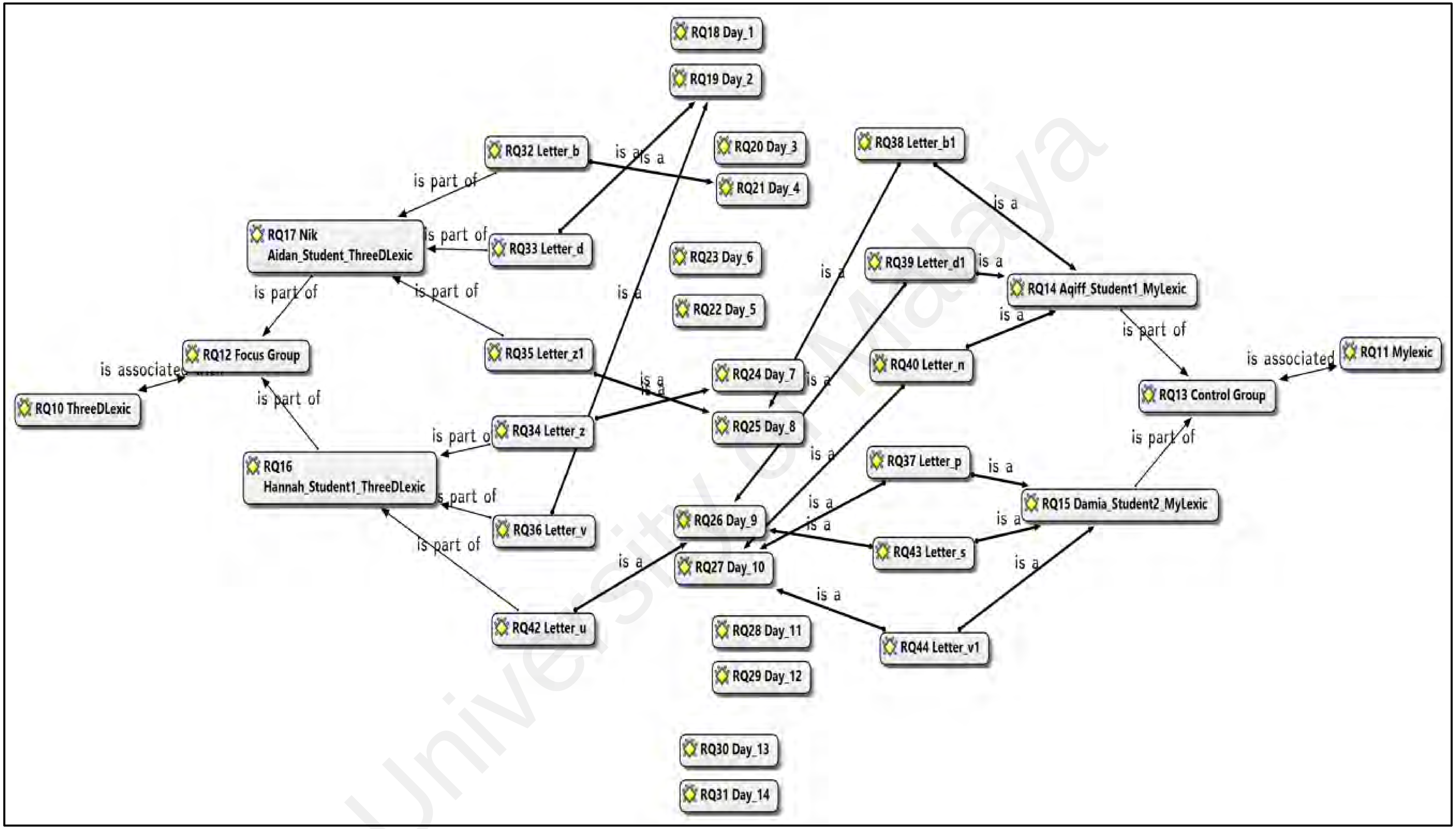

Figure 6.9 : Diagram for Comparisons on Day to Day Level of Achievement for Both Experimented Groups

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Figure 6.10 : Photos Showing Four Respondents Using 2D And 3D Prototypes

This analysis did not look at the previous achievement of each participant. It focused on the letter and the shortest time taken for any participant to write it correctly. It is found that as early as on day two and four, one participant (RQ17) had correctly written letters ‘b’ (RQ32) and ‘d’ (RQ33) using the 3D prototype. While using the 2D application the quickest time taken to write the same letters was on day seven and day eight. The same achievement was recorded for letter ‘v’, where respondent RQ16 wrote letter ‘v’ correctly on day two using 3D prototype (evidence no. RQ10) and the same letter was written by respondent RQ15 on the tenth day by using 2D application (evidence no. RQ11).

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6.7.3 ACHIEVEMENT LEVEL BASED ON 2D-INITIATED AND 3D-INITIATED RESPONSE LETTERS

Lastly, the frequency of successfully written letters by the participants while using the 2D was 238. In particular, for 3D prototype, 245 times of correct numbers were successfully recorded. The findings revealed through Atlas.Ti using the data obtained from the Monitoring Form for Mylexic Application 2D elements (Appendix D) and the Monitoring Form for ThreeDLexic 3D elements (Appendix E) are depicted in the graph below:

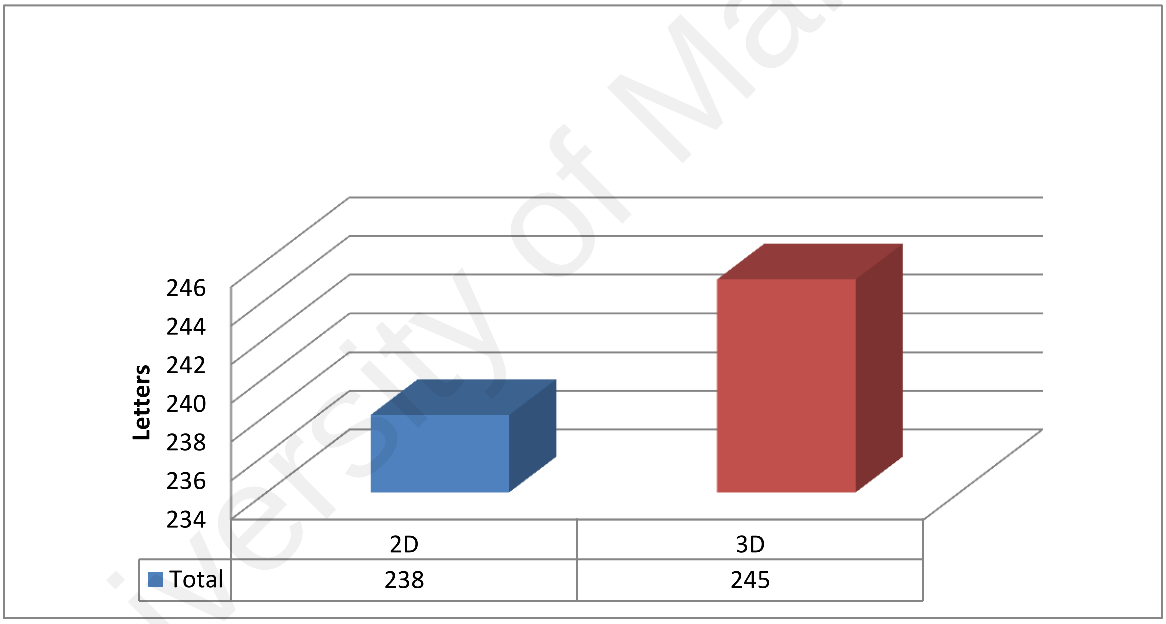

Figure 6.11 : Frequency of Achievement Using 2D and 3D Letters

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6.7.4 ACHIEVEMENT LEVEL BY INDIVIDUAL

To add richness to the findings, another way of analyzing was executed. This time, analysis was done to see how well the individual participant could write the letter and which letter was preferably well written. The second graph is the achievement level of dyslexic children by individuals.

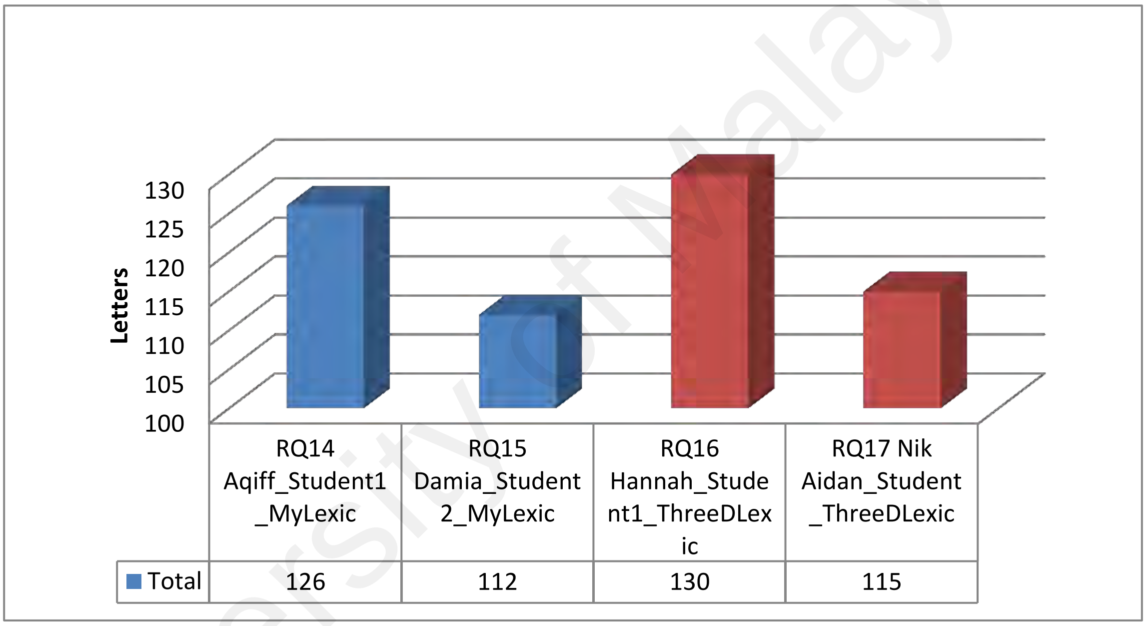

Figure 6.12 : Dyslexic children Achievement Level

The above figure 6.12 records the level of achievement of dyslexic children by individuals based on the frequency of getting the letter written correctly. For 2D application, Participant Aqiff recorded 126 letters written consistently for 14 days using the Mylexic application (2D element). While participant Damia recorded a total of 112 letters. The total is 238 letters. While for ThreeDLexic prototype (3D prototype) Hannah and Aidan recorded a total of 130 letters and 115 letters respectively. The total number is 245 letters.

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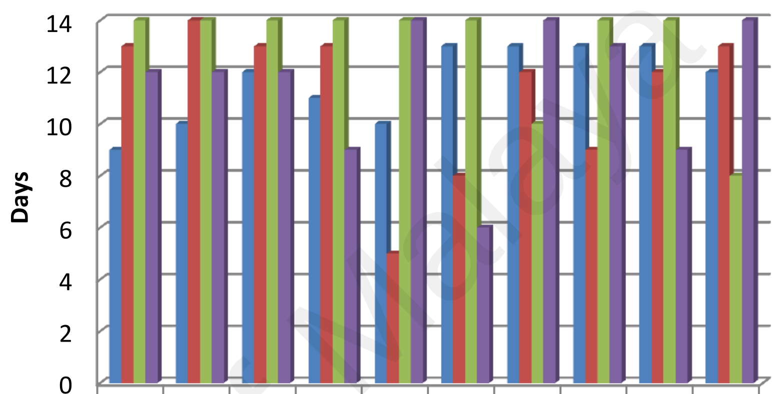
6.7.5 ACHIEVEMENT BY NUMBER OF DAYS

Finally, to unbury the depth of the achievement, analysis was done to investigate the number of days that the participant took to get the letter written correctly. The results are as below: -



	b	d	m	n	p	s	u	v	w	z
RQ14 Aqiff_Student1_MyLexic	9	10	12	11	10	13	13	13	13	12
RQ15 Damia_Student2_MyLexic	13	14	13	13	5	8	12	9	12	13
RQ16 Hannah_Student1_ThreeDLexic	14	14	14	14	14	14	10	14	14	8
RQ17 Nik Aidan_Student_ThreeDLexic	12	12	12	9	14	6	14	13	9	14

Figure 6.13 : Findings Based On The Number Of Days To Get The Letter Correct by The Participants

There were four pupils involved; two of them (RQ14 and RQ15) were observed while they were using 2D MyLexic while another two pupils (RQ16 and RQ17) were observed while they were using ThreeDLexic. For letter 'b', participants took 23 days to write letter 'b' correctly via 2D and 26 days via 3D application. For letter 'm', 24 days were taken via MyLexic while 26 days were taken via ThreeDLexic. Letter 'n' was reported to take about 24 days via MyLexic as opposed to 23 days via ThreeDLexic. To get the letter 'p' correct for the first time was 28 days via MyLexic while 15 days via ThreeDLexic.

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6.8 DISCUSSION

Throughout the thorough analysis enabled by the triangulation of multiple data sources and methods, it is evidenced that the 3D-assisted multimedia elements support the enhancement of letter writing among the dyslexic children. To sum up, the following Figure 6.14 illustrated the connections between the aspects of studies used.

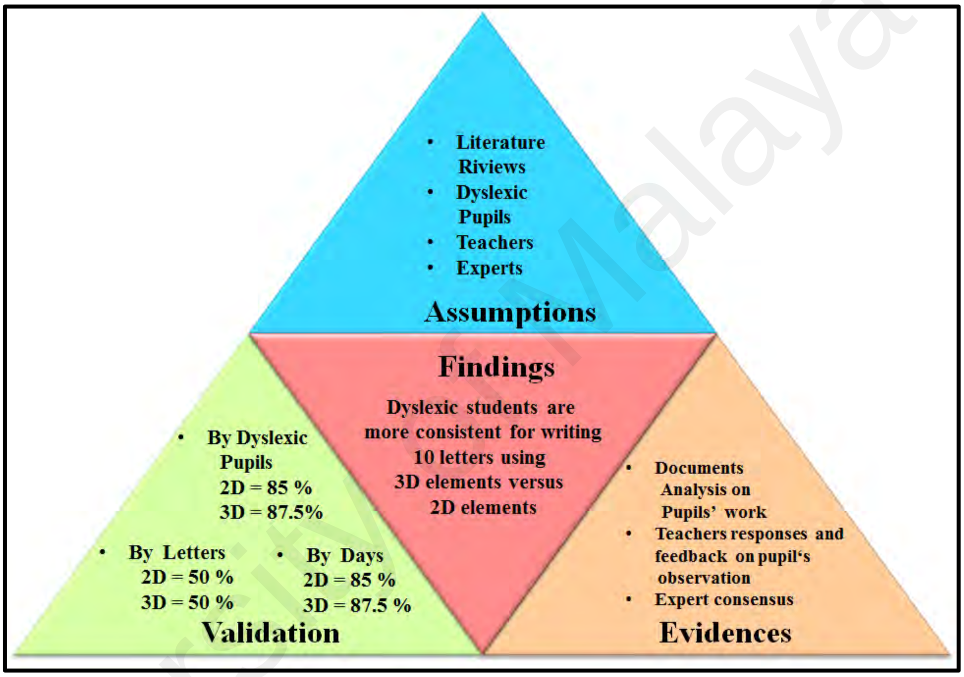

Figure 6.14 : Analysis Through Triangulation in 3D Interactive Animation Learning for Dyslexic children

There are four main elements involved in the triangulation process. These are Assumptions, Validation, Evidences and Findings. Drawing upon the assumptions derived from literature review, performance of dyslexic children, opinions from experts and teachers, evidences were collected which were subjected to various validation methods ie by triangulation.

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The study has yielded three types of validation; findings derived by individual participant, by letter and by progressive day. The use of 3D elements has recorded an increase of 7% in consistent letter writing among the participants. This was calculated when initially, 2D elements show 85% of consistent correct letter writing while the 3D elements recorded 87.5 %. The percentage was based on the first group of children who did not write consistently for 280 times during observation. This group only managed to write 238 times while using the 2D application. For the second group, they were found to have written correct letters consistently for 245 out of 280 times after being introduced and exposed to 3D elements. This suggests that the 3D elements or characteristics or features in this prototype have successfully improved the capability of the children to write correct letters consistently at about 7%.

While by letters, equal results were yielded by both 2D dan 3D whereby 2D and 3D groups achieved 50% respectively. Table 6.12 summarises ten letters of 2D dan 3D written consistently.

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Table 6.12 : List Of The Letters Wrote By Dyslexic children After Using 2D Application and 3D Prototype

Group 1 with 2D Element Letters Wrote Consistently	Group 2 with 3D Element Letters Wrote Consistently
n	b
s	d
z	m
w	p
u	v

From tables above, five letters considered as ‘difficult alphabets’ can be written consistently by dyslexic children after using ThreeDLexic. This finding show that dyslexic children are also visually impaired which adheres to the Dyslexic Syndrome Theory by Levinson (1994, cited in Noor Aina Dani, 2013).

> “Examples of force imbalances in the case of letters with words visually or phonetically are obvious for letters ‘b’ and ‘d’, such as 'was' with 'saw', 'on' with 'no', and 'god' with 'dog'.” (Noor Aina Dani, 2013)

So these difficulties can be overcome by using 3D letter elements in any prototype built specifically for dyslexic children. It turns out it can overcome the difficulty of writing and reading for these five letters (b, d, m, p and v) or any word collection that involves these five letters.

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6.9 SUMMARY

Based on the results, it paves to a conclusion that the use of 3-dimensional based prototypes was far more effective for dyslexic children compared to the use of 2-dimensional based applications. The next chapter extends on the conclusion of the research.

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CHAPTER 7

SUMMARY AND CONCLUSION TO THE RESEARCH

7.1 INTRODUCTION

In Chapters 4 to 6, researcher presented the data analysis and the findings. Each chapter built cumulatively upon the previous chapters. In Chapter 6, the focus was on understanding the design and development of ThreeDLexic prototype while discussing the results and findings on its implementation gathered from teachers and experts.

In this final chapter, the research questions and research aim are revisited to give a coherent overview of the thesis. It starts with the summary of the whole thesis beginning with the rationale, followed by a summary of research questions and aim. It then moves on to discuss the implications of these findings. Suggestions, strengths and limitations of the study are also given. To conclude, some reflections are presented as to further avenues of research.

7.2 SUMMARY OF THESIS

This study was an attempt to develop a 3D prototype that will assist the learning of alphabets among the dyslexic children. The current intervention that involves the computer technology found thus far is the 2D application namely MADRIGALE, Mylexic, Dyslexia Baca, MathLexic, Bijak Membaca and E-Z Dyslexia Courseware.

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From the literature review, the multimedia elements, as used in existing 2D applications, in particular the combination of sound, animation and graphic, have been proved in numerous studies could help dyslexic children learn better. However, to date, very limited literature has documented the use of 3D or any kind of objects animated in 3D format in such application, particularly for the dyslexic children. The 3D elements with animation and movement such as rotation and looping that works partially like a video format, is very rarely used as the learning tools for dyslexic children. Ironically, at the same time, numerous studies in other fields of education such as in science discipline, have documented the effectiveness of 3D technology as learning tools. With the mushrooming of the android technology that can be used as a mobile learning platform, the 3D learning experience has been enhanced by educational technologists. Thus, the researcher felt it is highly timely to develop an prototype based on the 3D prototype that would be applied on the android platform specifically for the dyslexic children in Malaysia.

7.3 RATIONALE FOR THE STUDY : THEORETICAL UNDERPINNING

The theory that underpinned this study or specifically the design and development of the 3D prototype was adopted from instructional design model, namely Addie, proposed by Rosset in 1987. Addie is an acronym that stands for and represent the processes or the phases involved, ie analysis, design, development, implementation and evaluation. Several constructs were considered for the development of the prototype pursuant to the review on the relevant body of literature. The ease of instruction, the layout of 3D menu options, the content level, the multimedia elements such as audio, animation (ie

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rotation), color scheme and the like served as the constructs that were investigated to inform the development and design of the ThreeDLexic.

Departing from the rationale and the gaps identified, one big question arose: How does 3D technology can help dyslexic children? As the research progressed, reflection on the research practice was constantly made. My reflections resulted in three research questions that guided the data collection and analysis for Phase 1 (Need Analysis Phase: preliminary study). The processes of constant reflection benefitted from reflexive practices and helped to determine the method of data collection and analysis for Phase 2, as explained in Chapter 6.

Informed by an extensive literature review, researcher gathered five constructs that could be used to understand the development of a 3D learning tool: ease of instruction, the 3D menu opitons layout, the content level, the multimedia elements such as audio, animation, rotation, combination of brightness and color schemes. A prototype was then developed which was informed by these constructs against the backdrop of Addie model.

7.4 METHODOLOGICAL OVERVIEW

This study adopts a mixed method design for data collection and analysis. This approach supports and illuminates the findings from quantitative and qualitative analysis simultaneously, particularly when dealing with latent variables such as the observed behaviour of dyslexic children and the opinions from both the experts and teachers. Initially, during the preliminary stage, data were collected using a standard

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assessment instrument used as a diagnostic tool to determine the problematic reversal letters from 150 pupils from which a set of 115 documents were analysed through document analysis. Later, series of observation was done on six dyslexic children while they were using a 2D application to inform the constructs needed to be attended when designing a 3D prototype. The observation and the document analysis served as heuristic devices to gauge aspects of content and multimedia elements to be considered in designing the prototype of ThreeDLexic. This has been elaborated in Chapter 5.

Once the prototype was designed, it was then test run to ten experts and their opinions were gathered through an online survey. Their consensus was analysed and reported in Chapter 6. At the same time, another series of observation were conducted together by the researcher and another four teachers on four selected dyslexic children based on the teachers' recommendation on their continuous close monitoring on these students. These two phases of data collection and analysis helped to answer the research questions, research aim and objective. The following sections recap the methodology and findings.

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7.5 RECAP: THE METHODOLOGY AND FINDINGS

To gather the information that enables me to answer this question, an extensive review on the body of literature encompassing two big related fields namely, the pedagogue for DC (education field) and the educational technology (computer science field) were executed. Thus far, the common intervention used for dyslexic children evolves around the 2D learning aids. There is a proliferation of 2D computerised programmer invented by many researchers. One of the characteristics of 2D that helped the learning is the level of instructions given whether it is easily understood, or not. Second, the way the menu was arranged on the screen that attracts the children to choose. Third, is the content level, whether it is for beginner, intermediate or advanced learners. This particular feature relates to the level of student's attainment or progress.

To measure the responses to this question, a self-reported standard assessment instrument was analysed. The document analysis executed has determined ten meaningful problematic reversal letters demonstrated by the children. These were as follows: 'b', 'd', 'p', 'w', 'm', 'u', 'v', 's' and 'z'.

Simultaneously, a series of observations by teachers via recorded video and a form on the participants behaviour and responses towards the following aspects (ie the layout arrangement of the menu, together with the content level, the instructions, the multimedia elements the observation on six dyslexic children) has suggested the characteristics of the design to be developed in the then-newly built 3D prototype, namely ThreeDLexic. The layout arrangement of the menu, together with the content level, the instructions, the multimedia elements were carefully scrutinized via the video that recorded the participants behaviour while using the 2D apps using Atlas Ti and was presented in Chapter 4.

The findings suggest both inconsistencies and consistencies between the predicted (assumptions) and realistic outcomes. Hence, all the considerations were taken into

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account in designing the prototype. Of equal importance, the finding verifies the utility of the 3D prototype on the android platform to aid the learning of the DC.

The prototype was subjected to ten experts and four dyslexic children. The ten experts opinions arrived at a consensus whereby the characteristics of the 3D prototype were agreed consensusly as potentially aiding the learning of alphabets by dyslexic children. The findings marked the starting point for the triangulation with observation data. The aim of triangulation was to extend the understanding of the impact of 3D-based technology intended to illuminate the relevant factors influencing the learning of dyslexic children.

To do this, researcher then carried out a comparison between the existing 2D applications and the 3D prototype by observing four children using both the applications. This was done using the data observed using video recordings and analysed using AtlasTi. Careful scrutiny and interpretation led me to categorise these letters into two groups, based on its difficulty, namely Group 1 with 2D Element Letters Wrote Consistently and Group 2 with 3D Element Letters Wrote Consistently. The most distinctive difference was seen in the letter rotation in which participants showed substantive improvement in writing considerably difficult letters exemplified by ‘b’, ‘d’, ‘m’, ‘p’ and ‘v’. This is a very huge improvement considering the previous findings that show very little hope in helping this category of letters.

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Before researcher began the qualitative analysis, researcher did a descriptive statistical analysis on the experts' feedback. Using FDM, the ten experts' responses were analysed to illuminate the areas of strengths and weaknesses of the prototype. The results led to an overarching finding that the difference between 2D and 3G based technology could make a substantive impact in the dyslexic children learning. These findings form the conclusion for Chapter 6.

From my analysis and interpretation, researcher conclude that the type of instructions alone, even though is crucial, would only be able to help children to choose the alphabets for their learning activity in a limited or minimum means. This characteristic, if joined with the layout of the menu to be chosen in a rotating manner would further attract children's focus to retain their interest in the activity until the end hence achieving the learning objectives. Further more, with a careful consideration on the content level coupled with the sound, animation, layout graphic and color scheme, the learning experience for the children could be deliberately further enhanced.

In sum, the analysis revealed a main issue pertaining to the 3D design of the ThreeDLexic prototype. All this while, we tend to ignore the capability of these children to learn better with the help of the today's technology; all this while, teacher's ignorance in identifying the best way to attract the focus of these children in learning the alphabet effectively has been ruled by a stigma that these children is a handicapped human kind and that effort to help them is unworthy. However, through this study, it is evidenced that these type of handicap group of people ie dyslexic is a special handicap whereby their genius level could be at par or above par of that a normal child.

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7.6 CONSTRIBUTIONS TO THE THEORY

This section, while addressing the study's contributions and implications, also serves as an extended discussion on the work carried out in light of the findings. Considering the absence of explicit discourse regarding the design of the 3D prototype for dyslexic children, there are three areas to which I hope this study has contributed.

The findings argue for the critical need to look at software design and development from the perspective of an individual teacher as a learner. When the developers of such application are those from the educational background and possessed personal experience teaching this group of children, the sense of belonging smoothly propels the journey. The study points to the possibility of developing the special needs teacher as the application developer due to the elevating interest of dyslexic children in computerised program. In most of the literature, reseacher found that the prominent people in the world, such as Einstein, the scientist, Tom Cruise the actor, George Washington the War general, among others were once the dyslexic children, who were then successful renowned people in the world. These people exemplified the unique capability dyslexic people possessed.

The application of FDM together with observation analysis using Atlas.Ti in this study was clearly a strategic method. FDM was able to illuminate and extend my understanding of the significant features or characteristics of a 3D prototype perceived by two-field experts. It fortifies the choices made upon the need analysis findings during the first phase. The results from document analysis and Atlas.Ti, together with the

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statistical results of FDM demonstrate the robustness of the methodology used in this study which serve as a complementary strategy.

The findings should be taken as a reflection on the current practice of teaching the dyslexic children in achieving the wider aim of learning with specific reference to the current agenda of lifelong learning. Teachers are to take stock on whether their participation and engagement in teaching this group of children is helping them to acculturate the sense of being part of the citizenship. Reflecting back to Malaysian National Philosophy of Education (NPE), as teachers, the findings may be taken as a measure to gauge the extent to which our role to make this world a better place for all children is fulfilled.

7.7 STRENGTHS

The research successfully gained concrete commitment from experts, teachers and dyslexic children. They are from two big different but related fields, education and applied technology. The triangulation of data source, methods and time has helped me to conduct a robust analysis that led to great contribution that add to the body of the knowledge. It is noteworthy that the research has helped dyslexic children to improve their performance in Bahasa Malaysia as the national language. Due to that, there are a huge amount of knowledge gained during the ThreeDLexic development process:

- Value of knowledge gained from the literature review and analysis on findings (data).

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- Value of knowledge gained during the development process of application with 3 dimensional environment.
- Applying the technical knowledge especially for the programming language used.

This study does not generate a comprehensive unique understanding to the discourse of dyslexic children learning as a whole. However, with 174 participants while utilising both quantitative and qualitative methods approaches of data collection, analysis, within the capacity of a single researcher, it is a significant achievement to have a 100% response rate for each of the data collection executed.

7.8 LIMITATIONS

During the implementation of this research, there were many constraints faced by the researcher. However, the researcher managed to overcome those constraints with assistance from various individual and organisations. The constraints are divided into two parts:

i) Social Constraints

- Issue of support from parents
- Issue in support from dyslexia children
- Issue of support from experts from various fields
- Term of research that involved school holidays

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ii) Technical Constraints

- Needs for hardware and software that required a 3D environment
- Issue of acquiring suitable tablets with android platforms

7.9 SUGGESTIONS FOR FUTURE RESEARCH

As the research progressed, a few potential improvements were consistently identified. These are suggested as future enhancement categorised in two aspects:

i) Enhancement from Technical Aspect

ThreeDLexic prototype will be uploaded into the Google cloud to make it easier for users to access.

ii) More animation characteristics will be added.

3D objects will be newly designed and not taken from existing design. Besides, adding characteristics of audio such as sounds of letters phonically to enhance users' learning experience will be helpful.

iii) Enhancement from Methodological Aspect

Implementations of research by using a fully quantitative method to capture broader audience and broader issues, increasing the number of experts from 10 persons up to 30 persons in the process of application evaluation using FD and extending the period of collecting data are aspects that could be considered for future take off.

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7.10 REFLECTION AND CONCLUSION TO THE RESEARCH

The journey to unveil the answers to my queries had crafted a winding pathways encapsulated in this invaluable study. To this end, researcher learnt that finally the answers to my queries that prompted this study are not that crucial to me now. Unlike the initial moments the researcher started the study whereby finding answers was so mechanical to her, the reseacher gathered that as time passes by, what matters most is the experience of getting to know herself as a teacher to these dyslexic children and the meaning that it carries in the relationship with them. The researcher became more passionate to have more meaningful bond with my pupils. Now researcher realised that her hunches to adopt a dyslexic daughter was not a coincidence. It was all-fated to mould me to become more tolerate, approachable and more understanding. In quadrat roles as a teacher, learner, mother and researcher, researcher learn to see herself and the bond created between me and the children as a way to manifest my promise that once researcher pledged when researcher decided to become a teacher. Thus, the findings of this study is not an ending, it is just a beginning.

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