NUMBER SENSE EDUCATIONAL GAME DESIGN FOR DYSCALCULIA AND LOW NUMERACY CHILDREN

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Thesis submitted to Dean of Awang Had Salleh Graduate School in

Partial Fulfillment of the requirement for the degree

Master of Science in Information Technology

University Utara Malaysia

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Abstract

Dyscalculia is a specific educational difficulty which affects an individual's acquisition of basic concepts of numbers and prevents them to understand and apply number facts. Dyscalculia can effect on different aspects of learning and performance mathematical skills, but number sense is the most affected issue by Dyscalculia. Studies indicate that approximately 5–8% of school-aged children experience difficulties to understand number sense. Mobile devices with installed educational games help these individuals feel more comfortable and relaxed doing and understanding mathematical skills. The main objective of this study to propose an effective educational game design guideline for learning number sense for Dyscalculia and low numeracy children. The methodology of this study has five stages which are: awareness of problem, suggestion, development, evaluation and conclusion. Every stage involves activities and output. This study also describes the design, implementation, and evaluation of the 123GO app a mobile educational app that is designed and developed based on the guideline. The principle design of 123GO app based on used the interaction design (IxD) that allowed to identify and apply for an educational game app that can be used by children that have difficulties with low numeracy and thus number sense problem. The evaluation of the app suggests that it is useful and easy-to-use. In conclusion, based on the evaluation results, it is found that the 123GO app is effective in helping Dyscalculia children with number sense difficulties.

Abstrak

Diskalkulia merupakan masalah spesifik pembelajaran yang melibatkan perolehan konsep asas nombor dan mengekang mereka daripada memahami dan mengaplikasikan fakta berkenaan nombor. Diskalkulia boleh memberi kesan ke atas pelbagai aspek pembelajaran dan prestasi matematik, namun deriaan nombor (*number sense*) adalah yang paling terkesan oleh Diskalkulia. Beberapa kajian menunjukkan bahawa lebih kurang 5-8% kanak-kanak sekolah mengalami kesukaran untuk memahami deriaan nombor. Peralatan mudah alih yang dimuatkan dengan permainan pembelajaran boleh membantu individu ini merasa lebih selesa dan senang melakukan dan memahami kemahiran matematik. Objektif utama kajian ini ialah untuk mengetengahkan panduan reka bentuk permainan pembelajaran yang efektif bagi mempelajari deriaan nombor kepada kanak-kanak Diskalkulia dan mereka yang mempunyai keupayaan numerasi yang rendah. Metodologi kajian melibatkan lima peringkat iaitu: kesedaran permasalahan, cadangan, pembangunan, penilaian dan kesimpulan. Setiap peringkat melibatkan aktiviti dan output. Kajian ini turut menerangkan tentang reka bentuk, implementasi, dan penilaian terhadap aplikasi 123GO yang direka dan dibangunkan berdasarkan panduan tersebut. Prinsip reka bentuk aplikasi 123GO ialah berasaskan reka bentuk interaksi (IxD) yang boleh diaplikasikan kepada aplikasi permainan pembelajaran yang boleh digunakan oleh kanak-kanak dengan masalah keupayaan numerasi yang rendah dan juga masalah deriaan nombor. Penilaian aplikasi tersebut mencadangkan yang aplikasi ini berguna dan mudah untuk digunakan. Kesimpulannya, berdasarkan keputusan penilaian, aplikasi 123GO ini adalah efektif dalam membantu kanak-kanak dengan kesukaran deriaan nombor.

Acknowledgment

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

First and foremost, all praise to Allah for providing me with the strength, perseverance, and wisdom to have this work done on time.

I would like express my deepest gratitude to my supervisor, Dr. Husniza binti Husni for his intellectual guidance and kind support given to me during the period of this study, as well as giving necessary advices and guidance and arranged all facilities to make my study (master information and technology) easier.

I dedicate this thesis to my wife Huda Zaki Naji and my daughters (Sarah and Farah) who unremittingly supported me during my years of study. They made this work possible.
I want to express my gratitude and dedicate this thesis to my father and my mother. they are continuously praying and encourage me and expresses confidence in my abilities to complete my study.
I am deeply grateful to my family (Ahlam, Mohammed, Ali, Hanaddi, Hiam, Fatima) for their love and support during my Master studies. I truly could not have achieved this milestone without their support.
I am also grateful to my brother (Al-Sheikh Jasim Al-kradi) for his help and inspiration and his praying throughout my study.

I say thank you to the staffs of Information and Communication Technology, College of Arts and Science, University Utara Malaysia and those that contributed indirectly towards the success of my studies.

Thank You All.

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CHAPTER ONE

INTRODUCTION

1.1 Research Background

Dyscalculia means some specific educational difficulties which affects an individual's acquisition of basic concepts of numbers and prevents them to understand and apply the number facts (Mangal, 2007). This difficulty appears in the form of inability to deal with numbers and figures ordering it from top to bottom or from bottom to top and putting them in larger or smaller quantities and understanding them without counting. This leads to problems in learning the facts about numbers and steps to solve arithmetic problems, while some believe that particular mathematical disorder of logical thinking. The first definition of Dyscalculia presented by Kosc (1974) that "the difficulty in the level of mathematic abilities caused by deficiencies exist in parts of the brain responsible for calculating perception without being accompanied by disorders in the general mental functioning

The most prominent symptoms of this difficulty are (Butterworth, 2010):

1. Child has difficulty in accurately counting things.
2. The child finds it difficult to count descending more than finding counting upward.
3. Find it difficult to read successive numbers such as: 376985469396.

4. Some children are unable to understand numbers, for example, writes number six and nine.
5. Some of the children are counting on their fingers even if it was a simple process.
6. Child infects serious concern when involves any calculation issues.
7. Child does not realize quickly and automatically if 7+5 is equal to 5+7.
8. Difficult to accomplish computational mental processes.
9. Repeated difficulties in the account, and the confusion between the signs +, -, × and ÷.
10. The difficulty of differentiating between the number which indicates the smaller and large (<, >).
11. The inability to read a series of numbers, e.g. confusing 56 with 65.

The difficulties that affect individuals suffer from Dyscalculia are significantly different, although there are common identified characteristics. Difficulties are divided into four main areas (Butterworth, 2010; Butterworth, Varma, & Laurillard, 2011; Kucian & Aster, 2015; Jo Boaler, 2015):

- The brain injury: According to research, an injury to the brain is one reason for the calculations difficulties, which affect disorders of the brain to acquire mathematical skills (Kosc, 1974).
- Language difficulties: Dyscalculia often co-occurs with other learning difficulties such as dyslexia, dyspraxia, attention deficit and hyperactivity disorder (ADHD), and specific language impairment (SLI). It seems that proficiency in the language and the ability of verbal with a significant

impact on the achievement arithmetic generally for children with learning and children difficulties who have difficulty learning and suggested that the linguistic flaws that hinder reading may hinder the account.

- Cognitive deficiencies: Perception is the process by which the child recognize the information that received from others. The perception problems spread among children with learning difficulties that causes problems to recognize the symbols, signs and words, for example, the child confuses two signs (+, -) and some and confused (6, 9) and (2, 5).

- Number sense problem: number sense is the focus of attention; it refers to the understanding of the science of numbers, operations, and the relationship between the number and the method of the ability to deal with daily-life situations, that include the individual numbers. Number sense problem is often related to low numeracy.

Low numeracy can be defined as the disability to perform basic math functions (calculations, fractions, algebra, geometry), understand time, money, measurement, graphs, probability, and the disability to perform multi-step mathematics (Iuculano,Tang, Hall, & Butterworth, 2008). Windisch (2015) demonstrated that levels of these basic skills have increased over recent years among each of the children and young people. The European High Level Group of Experts on Literacy (Windisch, 2015) classifies low numeracy into three distinct categories:

1. **Baseline Numeracy:**

   Doesn't having a sound knowledge of numbers, measures and structures, basic operations, basic mathematical presentations and the ability to use appropriate aids that enable further development.

2. **Functional Numeracy:**

   The disability to apply basic mathematical principles and processes in everyday contexts at home, school and work (as needed for banking, payments, reading timetables, etc.).

3. **Multiple Numeracy:**

   The disability and willingness to use mathematical modes of thought (logical and spatial thinking) and presentation (formulae, models, graphs, charts) that enables a person to fully function in a modern society.

This categorization means numeracy is part of a continuum which allows policy makers and practitioners to define the level 'required by society' or to participate in society (EU High Level Group of Experts on Literacy, 2012).

As aforementioned Dyscalculia is a brain-based condition which makes it difficult to make sense out of numbers and mathematical concepts. Certain children having dyscalculia are not able to grasp fundamental number concepts (Andrews & Sayers, 2014). They strive to learn and memorize elementary number facts. Thus, Dyscalculia portrays somewhat similar traits as the low numeracy children however their cases may be more sensitive (Jo Boaler, 2015). They might be aware what to do in a mathematics class; however, they do not understand the reason behind doing it. In simple words, they do not get the rationale behind it.

Other children understand the rationale behind mathematics; however, they are not sure when and how to make use of their knowledge for solving mathematics problems. Dyscalculia can impact several and various aspects of mathematics learning and performance. The most generic issue is with "number sense" (Verschaffel, Greer, & De Corte, 2007). This refers to an innate comprehension of the way numbers work, and the way quantities on a number line are to be compared and projected. The majority of scholars concur that number sense is the fundamental notion of learning mathematics as number sense has proved to be among the most substantial factors in mathematical learning (Dunphy, 2007; Jordan et al, 2010; National Council of Teachers of Mathematics [NCTM], 2000; Verschaffel, Greer, & De Corte, 2007; Yang & Tsai, 2010). If children do not understand the fundamentals about the way numbers work, learning mathematics and applying it in day-to-day life could be quite frustrating (Butterworth, 2003).

What interesting to note is that poor number sense performers are found not only among children attending middle or elementary school but among pre-service teachers (Markovits & Sowder, 1994; McIntosh, Reys, Bana, & Farrel, 1997; Menon, 2004a; Reys & Yang, 1998; Yang & Li, 2008). As well it is proven that number sense problem failures stem from both innate disability and inappropriate textbook structure and instructional methods (Markovits & Sowder, 1994; Menon, 2004a; Reys & Yang, 1998; Yang & Li, 2008; Menon, 2004b; Yang, Reys, & Reys, 2009). Standard teaching methods, for instance, may be useful for children with innate number sense but fail to conceptually benefit the rest of the students, leaving them struggling with basic mathematical logic.

This is why developing number sense has become top priority in many contemporary schools and is a research topic of numerous academic studies. It is one of the present-day challenge for curriculum-builders due to the high importance of number sense for the subsequent development of students (Bobis, 2004; Dunphy, 2007; McIntosh et al, 1997; National Council of Teachers of Mathematics, 2000). Academics have been considerably aided by the technological advancement in their search for efficient tutoring methods (Bennison & Goos, 2010; Dick, 2007; Ruthven, 2007; Suh & Moyer-Packenham, 2007). For instance, Suh and Moyer- Packenham (2007), show how computer interference can be helpful in terms of building symbol-reality associations, easing the comprehension of mathematical algorithms by breaking them down into simpler components, and allowing pupils to follow their progress and see their mistakes instantly.

Zbiek, Heid, Blume, and Dick (2007) show how such methods turn mathematical instructions into vessels for the easier conduct of student's representational fluency. For instance, Suh and Moyer- Packenham (2007), show how computer interference can be helpful in terms of building symbol-reality associations, easing the comprehension of mathematical algorithms by breaking them down into simpler components, and allowing pupils to follow their progress and see their mistakes instantly, in addition to that, existing research has proved that multiple representations aid students understanding of mathematics and logical concepts (Goldin, 2002; Tripathi, 2008). When combined with the advantages of Sophisticated technology, these representations become a powerful teaching tool, serving the better education of children.

1.2 Problem statement

The majority of scholars concur that number sense is the fundamental notion of learning mathematics (Dunphy, 2007; Jordan et al., 2010; Yang & Tsai, 2010). If children do not understand the fundamentals about the way numbers work, learning mathematics and applying it in day-to-day life could be quite frustrating (Butterworth, 2003). As Butterworth (2010) pointed; "at the age 0-10 years, children can understand complementarities of addition and subtraction and retrieve some arithmetic facts from memory".

Butterworth and Laurillard (2010) referred to the importance of making an impact in the classroom, and the importance of using the principled way of developing the optimal pedagogy, which can lead to improved performance by the children. The syllabus of mathematics developed by the Ministry of Education, Malaysia in elementary school Malaysia (Ministry of Education, Malaysia, 2011), emphasizes on transforming the classroom mathematics pedagogy environment into computer play as well as engaging the numerical capacities amongst low achievers using dyscalculia-remedy-oriented features.

Computer play development based on Alessi and Trollip model (1991), could implemented by ten stages: definition a goal of model, design analysis, materials study, idea generation, lesson model design, flow chart production, storyboard production, implementation, review and assessment. Among the ten stages of implementation, the design stage is considered one of the most important stages in order to effectively achieve the pedagogical-approach objective.

Hinostroza and Mellar (2001) introduced the concept of the integrating mathematics pedagogy in the educational computer game have a point of view more clearly for prescription in the education of children using the computer to play. So that, a problem-based countermeasure oriented model of computer play designs do not take into account the children teaching, but also takes the implementation of the pedagogy approach.

Many studies emphasize the importance of using mobile devices and touch screens for the purpose of teaching children suffering from number sense (Baccaglini-Frank & Maracci, 2015). Due to the small size of the device's screen that helps children to focus the attention and provides a more intuitive interaction (Baccaglini-Frank & Maracci, 2015). For example, the study of Su et al. (2010) showed that mobile devices could be used to reinforce primary school children's number sense. In addition, the study of Yang and Tsai (2010) emphasized the importance of using mobile devices and touch screens to help teacher's teaching and student's learning in number sense.

Thus, Technology devices enable the participants with number sense to learn while playing with technology and that make them more interested (Der-Ching & Mao-Neng, 2013). Mobile devices with educational games help the individuals with number sense to feel more relaxed doing the activities (Nor Elleeiana, Nur Azah, Belinda, & Einly, 2015; Der-Ching & Mao- Neng, 2013). Since technology has been regarded as an important and effective learning tool for helping children develop better understanding of mathematics (Bennison & Goos, 2010; Dick, 2007; Reimer & Moyer, 2005; Ruthven, 2007; Suh & Moyer- Packenham, 2007), technology should be a relevant tool for promoting children's number sense.

However, few studies via technology have focused on helping children develop number sense (Hudson, Kadan, Lavin, & Vasquez, 2010; Su, Marinas, & Furner, 2010; Yang & Tsai, 2010). For example, the study of Su et al. (2010) showed that web-based tools could be used to reinforce primary school children's number sense. In addition, the study of Yang and Tsai (2010) applied the technology-based environment to help teacher's teaching and student's learning in number sense. Their findings indicated that "integrating technology into number sense teaching and learning not only could promote students' number sense, but also had a positive effect on student's attitudes towards the improvement of number sense. In addition, several studies suggested that students may learn more from multimedia based learning environment due to multimedia messages including words and visuals than what traditional teaching modes can do (Gegner, Mackay, & Mayer, 2009; Mayer, 2003).

Even though, Clark & Mayer (2008) used only words to teach the children counting and guessing without considering that merging of figures, words, and visuals with formulas enhances the illustration side to teach counting and guess of number sense (Clark & Mayer, 2008). Despite the appearance of numerous applications for Dyscalculia and number sense, there are many difficulties to use these applications that appear with some limited features (De Castro, Bissaco, Panccioni, Rodrigues, & Domingues, 2014; Der-Ching & Mao-Neng, 2013). These applications are not compatible with overall symptoms of number sense, especially related with the user interface design, a language and the busy screen (Poobrasert & Gestubtim, 2013).

Since "integrating technology into number sense teaching and learning not only could promote student's number sense but also had a positive effect on student's attitudes towards the improvement of number sense" (Gegner, Mackay, & Mayer, 2009; Mayer, 2003), there exist a need carefully design technology to other learning number sense. Another problem is that these applications are designed for English or Thai-speaking children and very few applications are available in different languages (Poobrasert & Gestubtim, 2013). Moreover, many available applications are very expensive such as; Talking calculators, Little Monkey Apps Friends of Ten and splash math.

Finally, Edutainment application is designed for children with a sense of which focuses on counting and guessing problems and value of spatial prepare addition to learning other skills, such as addition, subtraction, division and multiplication, which can help children useful way to communicate and interact with the community.

1.3 Research Question

It is necessary to answer the following research questions in order to finish this study and to find solutions to the problems discussed in the previous section:

1. What are among the design guideline for learning number sense for dyscalculia and low numeracy children?

2. How to design educational games for dyscalculia and number sense children?

3. How to evaluate the usability measure of the proposed design guideline?

1.4 Research Objectives

The main objective of this research is to propose an effective educational game design guideline for learning number sense for Dyscalculia and low numeracy children. This guideline is important as it provides the theoretical groundwork for interaction design (IxD) with a focus on components and elements most suitable for effective learning. The following sub-objectives are necessary to accomplish the main objective:

1. To construct educational game design guideline based on IxD dimensions of form, content and behavior.
2. To design and develop educational game prototype incorporating the guideline constructed in (1).
3. To evaluate the proposed design guideline of educational game using usability testing in terms of effectiveness, efficiency and satisfaction.

1.5 Research Contribution

This study aims to utilize the technologies to help the children with low numeracy and Dyscalculia through the design and implementation of useful and easy-to-use educational game for teaching and learning number sense. Essentially, the best design principle that stimulating fun to use and apply the appropriate principles of the game to learn the children with number sense. This study contributes a guideline for educational game design specifically for low numeracy and dyscalculia children. The importance of the study takes not only the children with Dyscalculia and low numeracy into account, but also the implementation of the pedagogy approach, which can be summarized shortly:

a. Participants who use technology devices are more interested in learning as these technologies combine playing with learning.
b. Teachers who depend on technology devices are more interest in learning, as these technologies more ease and flexibility being enhanced with Audio and Visual effects.

1.6 Research Scope

The study focuses on Dyscalculia and low numeracy children as well as the importance of mobile Apps to help them. In this study, five children are the respondent as suggested by Nielsen (2000), Marina, Norizan, Nor Ashikin, and Mohd (2011) from Sekolah Kebangsaan Mergong. The age of the children ranges from 7 to 9 years old (Kamaruzaman & Azahari, 2014) and three teachers who are trained to handle these children, participated in the prototype and usability test. The schools have special class for children with suspected dyscalculia and low numeracy.

The necessary information was reviewed from existing documents, journals and from interviews with teachers in the schools, who teach the children mathematics. In addition, design of the prototype mentioned in this study demands condition like the one set (Using Eclipse tool for Java language, Android platform, SQL, Play store) which facilitates the work and enables interaction with the users. Eventually, the observation and usability testing will be using to get feedback from users. The aim of principle design is to design the system, in essence, stimulate fun to use, and the application of those principles suitable for children game with number sense learning.

This research is not cover the performance of the children but only focusing on the design guideline the application details can be summarized as follows:

1. Level I: focused on basic principle of the sense of number, which is counting the numbers, pronunciation and writing. This is done through the use of colours and integrated audio effects.

2. Level II: this level is to define the value place of numbers for example, bigger and smaller moreover arranging the numbers in ascending and descending order.

3. Level III: focuses on guess figures and estimating measurements and focuses on the basic concepts in mathematics including addition, subtraction, multiplication and division.

1.7 Organization of The Dissertation

This dissertation proposes the number sense prototype of the mobile educational game for Dyscalculia and low numeracy children. This Chapter establishes the background of the study.

Chapter 2 provides related background and related works on all major research issues covered in the thesis. Firstly, the study briefly presents the rate of prevalence of Dyscalculia among some countries and assistive technologies for children with Dyscalculia and low numeracy. Secondly, it focuses on some related literature about assistive technology and mobile applications with the highlight at some of the existing apps, as a platform to help in the design of educational game app to improve the mathematical skills for Dyscalculia and low numeracy children. Thirdly, the interaction design (IxD) is adopted as a primary tool to determine which principle is the most suitable to design the prototype for Dyscalculia and low numeracy children with communication difficulties.

Chapter 3 provides the research methodology of this study. It consists of four main phases to solve the identified problem.

Chapter 4 explains the design and development of the prototype by using Eclipse tool for Java programming language.

Chapter 5 presents the result for evaluation the usability of new prototype of 123GO app.

Chapter 6 discusses the conclusion and future work of this research. In addition, the chapter includes the contribution of this research study and the limitation.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature concerning this study, explaining in detail the available apps for children with dyscalculia and low numeracy. Beginning with a detailed description of dyscalculia and its types, it then further factually clarifies how the assistive technologies for children with dyscalculia are used. It likewise elaborates on the concepts involved in this study, such as assistive technologies for children with dyscalculia using computer and mobile devices. Creative ways to support young children with dyscalculia are evolving through technology, which are becoming more accessible to educators.

2.2 Dyscalculia Disorders

The term “disability” according to the World Health Organizations International Classification of Functioning, Disability, and Health (ICF), is the deficiency and disability of body organs and structure, and restrictions in different types of activity (Vincent Onabajo & Malgwi, 2015) Disability may be caused by various factors: genetics, sickness, environment, or accident. Disabilities are classified into five main types:

(1) Mentally challenged or mental retardation (MR)

(2) Cerebral palsy (CP)

(3) Communicative disorders (DSL)

(4) Learning disability (LD)

(5) Attention deficit hyperactive disorder (ADHD) (Mago, 2014).

Learning disabilities arise from the neurological differences in each individual's brain structure and function, impacting how one receives, stores, processes, retrieves, or communicates information (Cortiella & Horowitz, 2014). A child with a learning disability learns differently from other students.

For instance, in the areas of cognition (e.g. attention and memory) a young person suffering from a learning disability has a different learning process compared to other students (Jaya & Geetha, 2004; Raja & Kumar, 2011). Of all the specific learning disabilities, the most common ones are reading dyslexia (Cortiella & Horowitz, 2014) and math and written expression dyslexia (Gersten, Clarke, & Mazzocco, 2007). Comparatively, more research has been done on dyslexia than dyscalculia, which is considerably under-researched (Gersten, et al. 2007).

In the medical field, a general agreement exists that the characteristic of dyscalculia, which is estimated prevalent at an average of 6%, is marked by an unexpected severe impairment in mathematics while there is no marked intellectual disabilities (Badian, 1999; Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Gross-Tsur, Manor, & Shalev, 1996; Landerl & Moll, 2010; Lewis, Hitch, & Walker, 1994; Räsänen & Ahonen, 1995; Reigosa-Crespo, Valdés-Sosa, Butterworth, Estévez, Rodríguez, & Santos, 2011). Dyscalculia is considered as the standard, broadly-used terminology for the difficulties in learning and in mathematics among children with learning disabilities (Mangal, 2007).

It prevents a child from obtaining basic skills in arithmetic necessary in doing mathematical calculations. Specifically, it is a learning disorder faced by pupils with severe difficulties in acquiring skills in mathematics (Raja & Kumar, 2011; Mohd Syah, et al. 2015). While the available literature used various labels, such as Mathematics/Mathematical/Arithmetic Learning Disability (MLD or ALD) and Mathematics/Arithmetic Difficulties (MD or AD), dyscalculia is more widely-used to name difficulties in learning basic mathematics in the general sense. While often used interchangeably, the different terms actually describe groups of children with different types of mathematical learning disability.

Children with a specific, possibly biologically-based, impaired number sense or mathematical learning disorder are usually referred to as suffering from MLD or DD (Butterworth, 2005). MD/AD, in another instance, frequently references the lowest 25-30% of diagnosed children, which is a larger group, who exhibits underperformance in mathematics. This could be due to any of a number of reasons, which includes environmental factors (Butterworth & Reigosa Crespo, 2007; Mazzocco, 2007). Below are a few of the different definitions of dyscalculia:

1. Developmental dyscalculia: While this type comes from a specific brain function impairment (Kosc, 1974; Shalev, Auerbach, Manor, & Gross-Tsur, 2000; Wilson & Dehaene2, 2007) the research community has not always fully acknowledged the existence of developmental dyscalculia. However, with more studies conducted about the brain, the neuroscience research field has been progressing on learning about this special condition (Wilson, Dehaene, Pinel, Revkin, & Cohen, 2006).

2. Acalculia: Neurological damage is pointed out as the cause for this condition when a person loses all sense of meaning of numbers. This type of dyscalculia is marked by a person's inability to perform basic calculations like addition and multiplication, while still retaining his/her understanding of numbers.
3. Pseudo-dyscalculia: In this case, an individual suffering from emotional blockage or having problems with confidence finds mathematics difficult.

2.3 Prevalence of Dyscalculia

Based on data during the last 20 years, there has been a substantial increase in the number of mathematical low-achieving pupils (Swanson, 2000). Using a range of definitions, studies on the prevalence of dyscalculia have been conducted. According to these prevalence studies across the countries, Dyscalculia is relatively uniform (with a range of 3–6 % in the normal population) despite the lack of definitional consistency. This data came from the population studies done in the England, United States, Switzerland, Germany, India, Belgium, Slovakia, Iran, Netherlands and Cuba.

In the first prevalence study conducted in Bratislava (Kosc, 1974), 375 fifth-graders, 199 boys, and 176 girls were selected at random from 14 fifth grade classes in 14 schools. Twenty-four children (6.4 %) were classified as having dyscalculia during the assessment; these were those who scored at or below the lower 10th percentile. The prevalence of arithmetic disabilities in 1476 American children in grades 1–8 from a single school was assessed by Badian (1999).

This study defined learning disability with a score at or below the 20th percentile. 6.4% of the children had arithmetic learning disabilities, either a specific learning disability or in combination with dyslexia. In one German city, 546 3rd graders were tested by Klauer (1992) from 26 representatively chosen mainstream classes. This study projected the prevalence of dyscalculia at 4.4 %, with girls slightly overrepresented.

In Switzerland, the prevalence of dyscalculia was estimated by Von Aster, Deloche, Dellatolas & Meier (1997) at 4.7%. This result came from a sample from four schools in Zurich where 279 second and fourth grade school children ranging from 8 to 10 years old were examined. The objective of the study by Lewis, Hitch & Walker (1994) was to find out how prevalent Dyscalculia is in the context of reading attainment.

The following parameter was used: if both arithmetic and aptitude scores of the child were above 90 and his/her reading aptitude score is below 85, he/she was classified with those who have a specific learning disability in reading. A total of 1056 children (497 girls and 559 boys) were studied. The results indicated the following learning disabilities among the children: 1.3 % with a specific arithmetic disability; 2.3 % with arithmetic and reading disabilities, and; 3.9 % of the population under study, the largest group, were children with reading disabilities. With the use of standardized academic achievement tests, this prevalence study by Hein, Bzufka and Neumärker (2000) saw the participation of both an urban and a rural population sample of German schoolchildren. In each area, eight school classes of third graders were tested (n = 181 and 182, respectively) 6.6 % (n = 12) of the rural and 6.59 % (n = 12) of the urban school children reportedly got significantly worse performance scores in arithmetic compared to their spelling tests.

The study by Ramaa and Gowramma (2002) in the Indian primary schools and a description of the procedures approved by two independent studies that sought to identify and classify children who suffer from dyscalculia. After factoring out other possible causes of arithmetic failure, two dyscalculia prevalence studies showed 15 cases out of 251 (5.98%) and 78 cases out of 1408 (5.54%). This proposed design by Mazzocco and Myers (2003) intended to address math disabilities incidences during primary school. Diverse groups of kids meet the criteria for math disabilities, based on which identification measure(s) are deployed for. Of the 209 partakers, 22 exhibited persistent MD for more than one school grade.

Desoete, Roeyers and De Clercq (2004) evaluated the incidence of mathematics learning disabilities (MLD) in Belgium, between 3% and 8% of the kids studying in elementary schools. Koumoula, Tsiromi, Stamouli, Bardani, Siapati, Graham, et al. (2004) utilized a community sample of 240 pupils in the age group of 7–11, studying in rural and urban schools. It was observed that there was no difference between genders as far as arithmetical performance was concerned; however, the impact of grade and socioeconomic level was noteworthy. Occurrence was higher in rural areas compared to urban. Barbaresi, Katusic, Colligan, Weaver and Jacobsen (2005) exhibited that MLD occurs often and is more prevalent in boys. Cumulative incidence rates of MLD for age of 19 were in the range of 5.9% to 13.8%. Subjects covered all kids born from 1976–82, who remained in Rochester, Minnesota after the age of 5 (N = 5718). Several kids with MLD (35% to 56.7%) did not possess a comorbid reading disorder. Barahmand (2008) evaluated the occurrence of arithmetic disabilities in Iran’s elementary schools.

A total of 44 children (3.76%) were seen to have an arithmetic disorder out of the 1171 boys and girls enrolled in grade 2 through 5. Prevalence rates for both genders were alike except for 4th graders, where more girl students were seen to have arithmetic disabilities. Dirks, Spyer, van Lieshout and De Sonneville (2008) evaluated the incidence of combined reading and arithmetic disabilities in 799 school kids from the Netherlands. The results revealed a percentage of 7.6. Geary (2010) recommended The Missouri Project for kindergarten to 9th grade study of over 200 pupils and their mathematical growth and learning. The author noticed that kids with MLD had extensive working memory deficits as well as specific deficits in their sense of number, which prolonged their learning of formal mathematics.

According to (Reigosa-Cresp et al. 2011), the prevalence of developmental dyscalculia in Cuba stood at 3.4%, while the male to female ratio was 4:1. The sample comprised (N = 11,652 kids). According to Wilson, et al. (2015), the developmental learning disabilities of dyscalculia and dyslexia have a combined prevalence of 10% or greater, and a co-occurrence (comorbidity) rate of about 40%. The sample covered 85 adults in the age group of 18–42 years, with 48 women and 37 men. Figure 2.1 depicts the prevalence of developmental dyscalculia among some nations.

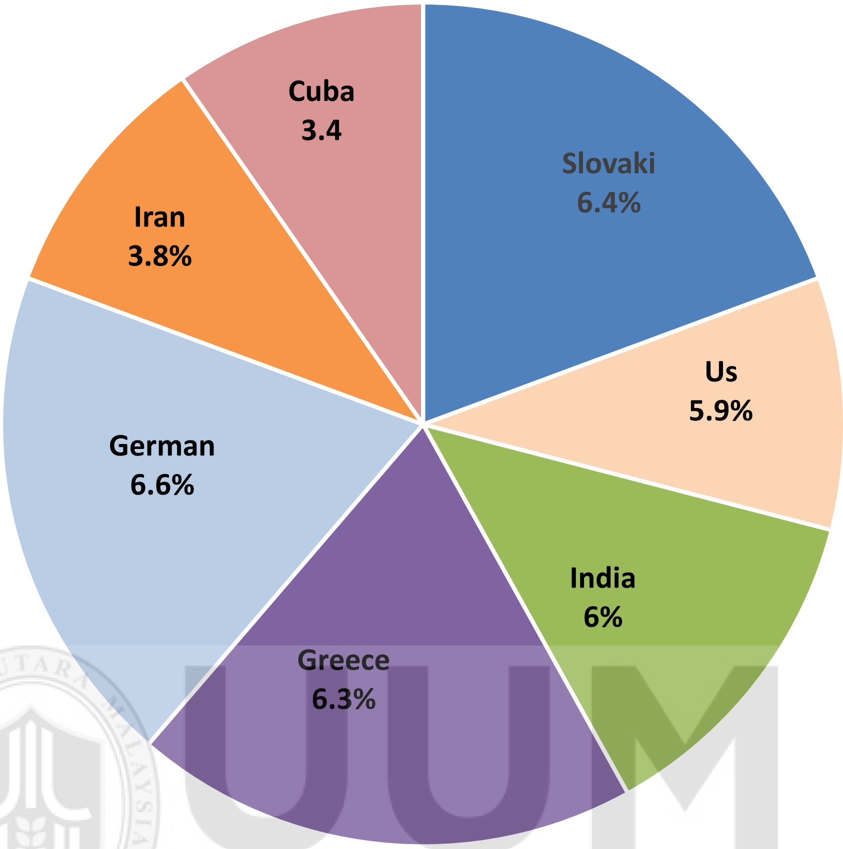


Figure 2.1. Depicts the prevalence of developmental dyscalculia among some countries

2.4 Number sense and Dyscalculia

As mentioned, the dyscalculia is a brain-based condition which makes it difficult to make sense out of numbers and mathematical concepts. Certain children having dyscalculia are not able to grasp fundamental number concepts. They strive to learn and memories elementary number facts. They might be aware what to do in a mathematics class; however, they do not understand the reason behind doing it. In simple words, they do not get the rationale behind it.

Other children understand the rationale behind the mathematics; however, they are not sure when and how to make use of their knowledge for solving math problems. Dyscalculia can impact several and various aspects of math learning and performance. The most generic issue is with number sense. This refers to an innate comprehension of the way numbers work, and the way quantities on a number line are to be compared and projected. The majority of scholars concur that number sense is the fundamental notion of learning mathematics. If children do not understand the fundamentals about the way numbers work, learning mathematics and applying it in day-to-day life could be quite frustrating (Butterworth, 2003).

2.5 What is Number Sense?

As Griffin (2004) noted; "What is number sense? We all know number sense when we see it; however, if asked to define what it is and what it comprises, the majority of America, including the teachers among us, would have a tougher time. Yet, this is exactly what we need to know to teach number sense effectively". In the field of education, number sense is the general comprehension of quantity involving zero, fractional and whole units that enables us to articulate quantitative relationships (this is known as "number knowledge" (Davydov, 1982; Jordan, et al. 2008; Malofeeva, Day, Saco, Young, & Ciancio, 2004; Berch, 2005). Number sense pertains to a person's overall comprehension of numbers, operations, and the relationship between these two. It also relates to the competency to tackle day-to-day life scenarios which involve numbers (Markovits & Sowder, 1994; Reys & Yang, 1998; Yang & Tsai, 2010).

Number sense is an elementary tool for carrying out day-to-day tasks, and involves different domains of knowledge. During the days of childhood, kids use it for activities such as counting pocket money, distributing candy among friends, and keeping a track of time while playing video games. During the days of adulthood, it is used for activities such as keeping a track of medication times, and keeping an account of receipts, payments as well as funds (Ginsburg, Klein, & Starkey, 1998; Dehaene, 2011). The transition between the quantitative dimension of the real world and the analytical one is considerably easy for students who have a keen mind for numbers and mathematical concepts. Such pupils have no problem devising their own methods for handling numerical problems and are able to play with the numbers in their minds to the extent of the purpose these numbers serve.

Their logical thinking makes numerical expressions easy to recognize, decipher, and place in the numerical hierarchy. It is also the reason behind their feeling of mathematical magnitude which increases their ability to spot large-scale mistakes pertaining to the magnitude dimension. Another amazing fact is their capability of comprehending and paraphrasing mathematical situations with a brilliant logic and in simple terms (Markey, 2009). Although placing a description of this "number sense" is not an easy task, its holders express some common features which make it easier to analyze for the purpose of better teaching of the mathematical sciences (Mohd Syah, Hamzaid, Murphy, & Lim, 2015). Recent years have seen numerous analyses and academic works on the number sense due the increased interest in its characteristics. Different researches have studied the issue from various perspectives and have reached a number of conclusions (Markovits & Sowder, 1994; NCTM, 2000; Reys & Yang, 1998; Verschaffel, et al. 2007; Yang & Li, 2008; Yang & Tsai, 2010) yet, they all recognize a five of common elements:

1. Thorough comprehension of numerical contexts.
2. Spotting correct numerical dimensions.
3. Ability to differentiate between representations and find their correct order.
4. Logical connection between numbers and the operations acting upon them.
5. Evaluating computer-based results through relative mind calculations.

2.5.1 Conceptions of Number Sense

Scientific research has so far presented several number sense conceptual facts (Strauss & Corbin, 1998):

1. Children with number sense display their logical sense of numbers from an early age (Butterworth, 2005; Ivrendi, 2011; Lipton & Spelke, 2005), starting with a ratio of 1:2 in terms of numerical awareness at the age of six months or so (Feigenson, Dehaene, & Spelke, 2004), and up to five-element mathematical distinction at the age of around four. Such brilliant logic has no connection to teaching processes during early childhood and proves to be a hundred percent innate (Dehaene, 2001; Feigenson et al., 2004).
2. FoNS (which stands for Foundational Number Sense), on the other hand, occurs at a later stage, when children start their formal education at the age of six or seven (Ivrendi, 2011; Jordan & Levine, 2009) and is something "that children acquire or attain, rather than simply possess" (Robinson, Menchetti, & Torgesen, 2002, p. 85) and "reflects, inter alia, elementary conceptions of number as a representation of quantity or a fixed point in the counting sequence" (Griffin, 2004).

3. Applied number sense finds practical expression in every mathematical aspect and operation, regardless of the specific mathematical area (Faulkner, 2009; Faulkner & Cain, 2013; NCTM, 1989). It alludes to the "basic number sense which is required by all adults regardless of their occupation and whose acquisition by all students should be a major goal of compulsory education" (McIntosh et al., 1992, p3).

2.5.2 Why Is Number Sense Important?

Teaching preschool and kindergarten math calls the use of number sense "making friends with numbers" (Burns, 2007). Number sense helps children develop logical thinking and eliminates their fear of mathematics (Carlyle & Mercado, 2012). Instead of getting chills just by mentioning numbers, pupils comprehend how logical and easy to work with they are, and that mathematical operations are as natural as everything else in life. On the other hand, children without innate number sense tend to approach even the simplest numerical operations timidly and with great unease, not to mention their panic facing more complicated problems. The University of Missouri recently carried out a scientific research in the field with 180 students in the seventh grade and concluded that those who lagged behind their peers in a test of core math skills needed to function as adults were the same kids who had the least number sense or fluency way back when they started first grade (Neergaard, 2013). Such an outcome of the study clearly shows why a fifth of the working population in the States knows less about math than an average student attending middle school, and therefore lacks proper qualification for a decent job.

2.6 Promoting Dyscalculia with Mobile Education Games

The learning opportunities for students with disabilities are quite different from the ones their healthy fellows benefit from. Conveying knowledge to such pupils, especially in cases of different levels of disabilities, can prove very challenging. Children suffering from dyscalculia or low numeracy, for example, can benefit by assistive technology in terms of the learning process. Such technology has proven to be very useful in making learning disabled children able to learn and draw conclusions on their own, as well as providing necessary support for them. Students suffering from dyscalculia have difficulties with language learning, logical thinking, and arithmetic, which in turn hinder their mathematical skills (Mohd Syah, Hamzaid, Murphy, & Lim, 2015).

Joint learning can prove to be quite useful in such cases, as children can use games in order to pass knowledge to one another (Mendes & Grando, 2008). Therefore, computer games can be used for educational purposes and can serve a greater cause than the regular source of entertainment (Yang & Li, 2013). The reason behind the efficiency of games in the learning process is the strong motivation they present to the children involved to be a part of something, to search for the right answers, and to strive for excellence (Ke, 2008; Papastergiou, 2009). This motivation is to a great extent caused by the role of entertainment in the process of inciting logical thinking (Mendes & Grando, 2008; Bottino, Ferlino, Ott, & Tavella, 2007). Stimulation is directly proportional to the interest the disabled student's exhibit towards the game (Wilson & Dehaene, 2007).

Another great advantage of computer games is that they present the right answers to the children immediately, which allows the pupils to see their errors, comprehend, and correct them right away. In this way, student's involvement in the learning process grows (Bottino et al., 2007). A large variety of computer games are nowadays available but few of them require logical thinking and computing skills which limits the choice of suitable games (Ke, 2008; Bottino et al., 2007; Seo & Bryant, 2009; Wilson et al., 2006). Examples of games suitable for cases of dyscalculia include Graphogame Math which helps children recognize and utilize numbers (Rasanen, Salminen, Wilson, Aunioa, & Dehaene, 2009), and Number Race which game promoting the distinction between numbers and values (Wilson et al., 2006). A special computer tool was also developed and tested among children with dyscalculia (Brunda & Bhavithra, 2010), and the results proved that such disabled pupils can benefit greatly from an innovative learning device like that.

2.7 Interaction Design

Interaction design (IxD) refers to the development of interactive products to support people in their daily lives. It characterises the behaviour of systems and is focused on form and content in relation to system behaviour and user input (Preece, Rogers & Sharp, 2007). IxD has three dimensions namely form, content, and behaviour, as shown in Figure 2.2. Form represents the physical structure of the interface and includes colours, fonts, buttons, labels, and figures. Content stands for what is being presented to the user.

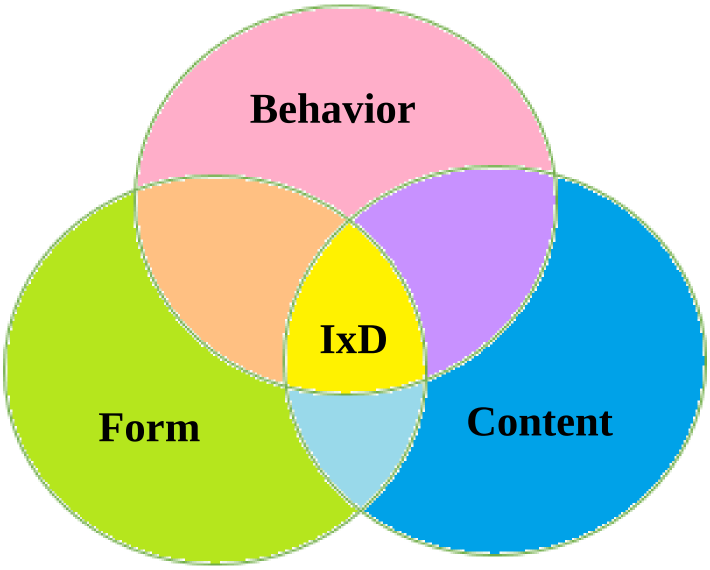


Figure 2.2. IxD Dimensions with Form, Content, and Behaviors

Finally, behaviour denotes how the content is presented to the user and is focused on user experience and feelings after accessing the presented content (Aziz, Husni & Jamaludin, 2013). This definition is useful for many aspects of design, although the precise focus on form, content, and behaviour will vary depending on the product being designed (Cooper, Reimann & Cronin, 2007). In addition, interaction design aims to produce good qualities. The definition of good depends on the design domain. Productivity devices are generally good if they support the professional goals of a user without violating personal goals (Jonas, 2001).

2.7.1 A Background On the Interaction Design

In the late 1970s and the early 1980s, innovative researchers, engineers, and designers in the San Francisco Bay Area were busily determining how people could interact with computers in the future. At Xerox Parc, SRI, and Apple Computer, people had begun talking about what it meant to create functional “human interfaces” for digital products (Cooper et al., 2007). In the mid-1980s, Bill Moggridge and Bill Verplank, both industrial designers working on the first laptop computer (GRiD Compass), came up with the term “Interaction Design” for what they were doing.

However, 10 years would pass before other designers rediscovered this term and brought it into mainstream use (Zou, 2009). Alan Cooper comprehensively developed the methodology (Alves, 2013). When it comes to design, human-computer interaction, software development, and interaction design (often referred to as IxD) are collectively defined as “the practice of designing interactive digital products, environments, systems, and services”. Similar to a variety of other design fields, interaction design also focuses on form, but its main concentration is on behaviour. Interaction design is clearly distinguished as a design field as opposed to a science or an engineering field in that it can be characterised as a synthesis and an imagining of things as they might be rather than how they actually are (Cooper et al., 2007).

Interaction design is a new design field of design that alters the relationship between humans and products from “use” to “interaction.” It focuses on interaction from both perspectives (human and product). Human-centred and user-friendly criteria inevitably become important components of product design (Hutchison, 2014). The software programs, development, and techniques as well as the progress of ideas that relate to ICT are not easy to check despite the fact that these services are continuously transformed.

These changes are brought about by the communication of the user with mobile software programs (Hutchison, 2014). Therefore, it is the duty of the interaction design experts to continuously improve models and design methods for programs such as technologies meant for locomotion, gestures, audio, touches, etc., which are programs that utilise interaction technologies. The technological assets for social communication and the assets for interaction as well as exchange of data need to work perfectly well with conventional methods which are not technical in nature (Milne, 2007). However, incorporating communication design into the use of software development has the tendency to boost the development process in order to aid building of products that are user-friendly, especially in meeting the needs and desires of the user (Jakob Nielsen & Norman, 2014).

2.7.2 An Effective Interaction Design

When in prototype design, the professional designers should understand the important areas in their program designs which impact on the emotional changes in the targeted users. For a product to succeed, it has to promote positive influences and avoid negative ones. Among these viewpoints are enthusiasms, positive, negative, resourceful, convincing, teaching and societal effects. The use of expressive points of interaction is one of the ways to communicate this viewpoint. In software, for example, the use of dynamic icons, sound, and animations can help communicate a state of operation, thus creating a sense of interactivity and feedback. To create effective interaction and communication, say in software, it is ideal to use changing icons, audio, and images which will aid the expression of the operation.

The strength of the interface can be influenced by colour palettes, graphical arrangements, and fonts which are components of interface viewpoints. Studies show that effective aspects can affect the perception of usability amongst users (Preece, Rogers & Sharp, 2007). Developers should place high emphasis on interaction design, especially within mobile applications, in order to maintain the core interface, functionality, and features (Petersen et al., 2014). This ensures that the interface, and overall design, can inspire participants to confidently use the prototype (Petersen, Baalsrud, Eds & Hutchison, 2014) and, more importantly, "interaction designers strive to create meaningful relationships between people and the products and services that they use, from computers to mobile devices, to appliances, and beyond," (Alves, 2013).

2.7.3 Interaction Design for Children with number sense problem

In context, this study deals with the use of edutainment apps in Malaysian Primary Schools, amongst children with dyscalculia. These students often devise their own methods of handling numerical problems, and are faced with a number of issues, such as the inability to mentally envisage numbers and the way they interact (Dehaene, 2011; Mohd Syah, Hamzaid, Murphy, & Lim, 2015). Support for such children typically begins early on in life, usually immediately after diagnosis, and involves a wide variety of visual tools. The visual tools such as text, images, and objects are used to represent both abstract and physical concepts (Butterworth, 2010). Mobile devices with educational games aid these kids to relax and at ease when performing such activities (Yang & Li, 2013). These games help children with number sense problem grasp concepts through an interactive manner, particularly by combining multimedia elements with tangible interfaces (Yang & Li, 2013).

Unfortunately, this approach also has its limitations, the most significant of which is that all mobile applications thus far designed to help individuals with number sense problem are found to be challenging to use due mainly to poor user interface design offering insufficient features (Al-Wakeel, Al-Ghanim, Al-Zeer, & Al-Nafjan, 2015). Apedd with number sense problem, including individuals with dyscalculia, need varying degrees of difficulty in using these applications compared to the general user (Barry, Kehoe, & Pitt, 2008).

Therefore, it is imperative that the software developer addresses the specific requirements of the target audience and adjusts the design accordingly (Shields, 1999). In the initial phases of this study, technology was demonstrated to be appealing to individuals with number sense. Nevertheless, to become an ideal platform of learning and comprehension for users with special needs, it was shown that interface design needs to be optimised (Barry & Pitt, 2006). Currently available applications designed to facilitate with cognitive impairment do not adequately emphasise the needs of children with number sense problem, but rather focus on the general user (Barry & Pitt, 2006). In this study, interaction design is utilised as a means to conceive design principles that can potentially be used to develop applications to enhance the mathematical skills of users with number sense.

2.8 Uses of Mobile Apps to Learn Mathematics for Children Dyscalculia and Number Sense

Number sense has proved to be among the most substantial factors in mathematical learning (Dunphy, 2007; Jordan et al., 2010; NCTM, 2000; Verschaffel et al., 2007; Yang & Tsai, 2010). What is interesting to note is that poor number sense performers are found not only among students attending middle or elementary school but among pre-service teachers as well (Markovits & Sowder, 1994; Menon, 2004; Reys & Yang, 1998; Yang & Li, 2008). It is proven that number sense problem solving failures stem from both innate disability and inappropriate textbook structure and instructional methods (Menon, 2004b; Yang et al., 2009). Standard teaching methods, for instance, may be useful for children with innate number sense but fail to conceptually benefit the rest of the students, leaving them struggling with basic mathematical logic. This is why developing number sense has become top priority in many contemporary schools and is a research topic of numerous academic studies (Yang & Li, 2008; Yang et al., 2009). It is one of the present-day challenges curriculum-builders face due to the high importance of number sense for the subsequent development of students (Bobis, 2004; Dunphy, 2007; McIntosh et al., 1992; NCTM, 2000).

Academics have been considerably aided by the technological advancement in their search for efficient tutoring methods (Bennison & Goos, 2010; Dick, 2007; Ruthven, 2007; Suh & Moyer-Packenham, 2007). For instance, Suh and Moyer-Packenham (2007), show how computer interference can be helpful in terms of building symbol-reality associations, easing the comprehension of mathematical algorithms by breaking them down into simpler components, and allowing pupils to follow their progress and see their mistakes instantly. Zbeik et al. (2007) shows how such methods turn mathematical instructions into vessels for the easier conduct of student's representational fluency. In addition to that, existing research has proved that multiple representations aid students understanding of mathematics and logical concepts (Goldin, 2002; Tripathi, 2008).

When combined with the advantages of sophisticated technology, these representations become a powerful teaching tool, serving the better education of children. Since all recent studies point to the vital role of number sense in children's education, it is evident that the educational system should include as many number sense exercises and activities as possible (Griffin, 2004; Yang & Wu, 2010), in order to enhance pupil's abilities to the greatest extent possible. Computer technology plays an essential role in the development of the number sense as it has already demonstrated its beneficial influence on mathematical and logical thinking. Bennison and Goos, 2010; Dick, 2007; Reimer and Moyer, 2005; Ruthven, 2007; Suh and Moyer- Packenham, 2007, marks the possibility of students helping each other in the learning process if they are provided with the proper technology (Der-Ching & Mao-Neng, 2013) which is currently not the case in the majority of schools (Hudson, Kadan, Lavin, & Vasquez, 2010; Su, Marinas, & Furner, 2010; Yang & Tsai, 2010). For example, the method of Su et al. (2010) points the great effect computer technology has on developing number sense in primary school students.

Also, the study of Der-Ching and Mao-Neng (2013) shows the practical side of online tools in the processes of teaching and learning. Therefore, it can be concluded that "using technology to teach the children with number sense not only could promote their understanding the mathematical skills but also had a positive effect on student's attitudes towards the improvement of number sense" (Gegner, Mackay, & Mayer, 2009). What is more, according to various researches, students learning in a high-tech environment are given the benefit of the multimedia messages and acquire knowledge faster and more efficiently than the ones educated via traditional academic methods.

Despite the fact that studies have proved the efficiency and outstanding influence of assistive technology on number sense (Der-Ching & Mao-Neng, 2013), the actual process of studying via such a technology has been exhibited in very few researches. We will therefore now focus on specific applications for number sense educational application:

2.8.1. Mighty Math

The main problem with students who suffer from dyscalculia and low numeracy is that their number sense is not keen enough for them to match numerical expressions to applications from their real life. Luckily, there are software applications, Mighty Math being one such example, which use visual effects and multimedia to engage children in practical games and show them the connection between the mathematical theory and the real world. This application does not contain the important basics on how to write and pronounce numbers and distinguish them from each other, thus it is difficult to use for children age 3-5. Moreover, the product has no recent updates and will most likely never have them. Also this product cannot be used offline (De Castro, Bissaco, Panccioni, Rodrigues, & Domingues, 2014).

2.8.2 Babakus

A great tool for helping dyscalculia children get familiar with the concepts of division, multiplication, addition and subtraction is the Babakus a conceptual mixture between the Abacus and the western slide ruler. It can be used by both students with logics problems and ones who have a good number sense but need more practice. It is also very adaptive to the children's level of advancement or the lack thereof. Despite the importance of this application for children with Dyscalculia and low numeracy, but this application is complex, because it requires reading the manual to work out how it works. Therefore, the children will face difficulty in using it without supervision by parents or teachers. Furthermore, this application is expensive at $ 20.99 in the UK app stores (Poobrasert & Gestubtim, 2013).

2.8.3 Talking calculators

Children can understand what they have pressed on a calculator in the case of talking calculator use, which is very helpful for students who tend to confuse numbers, for example 12 and 21. Using the talking calculator, they will feel more confident what they have pressed and will try to remember and imitate the action properly. The tool is especially helpful because the child does not have to look at the screen at all in order to find out if they hit the correct button, which will in turn make them more self-assured when moving from screen to paper exercises.

The market also offers handheld talking calculators but these naturally come at a higher price. While the talking calculator is the most efficient method for children to perform arithmetic calculations, it has two major disadvantages. First of all, reliance on the talking calculator does not afford the children the advantage of practice in the underlying steps needed to perform the calculation. One can use a calculator without actually understanding the underlying mathematical principles. Secondly, heavy reliance upon use of the calculator results in the loss of instant recall of the basic addition, subtraction, multiplication, and division facts (Poobrasert & Gestubtim, 2013).

2.8.4 Number Pieces Basic

Number Pieces Basic incites the multi-digit comprehension of disabled children, helps them understand place value better, and works towards building their number sense. It uses number pieces which students find easier to work with when performing the basic mathematical operations and properly marks their level of understanding even if they have certain difficulties with the numbers themselves. This product also has many technical limitations, for example, when child wanted to write 50-86 and then switch to the blocks the child had to click on the calculator function to switch modes.

Otherwise when child tried to click on the blocks, child would end up drawing on them. Also, child wanted an "undo" button. If the child accidentally clicked on a blocks pic to break it up, it would make a duplicate and child would have to delete it instead of pressing undo. This interaction is complicated and unsuitable for children (Der-Ching & Mao-Neng 2013).

2.8.5 Native Numbers

A very effective tool to introduce numbers to a child is the Native Numbers application. It uses concepts which are interesting to the children in order to engage them to actively participate in their debut in the world of mathematics. The application provides examples from the pupils everyday like animals, words, tallies, etc. and gives them numerical expression. The disadvantage of Native Numbers apps is: automatically adjust up the level of challenge regardless of child's age or him/her ability. Children are required to demonstrate proficiency in each concept or skill before moving on to the next. Also this product cannot be used without Internet connecting. Furthermore, this application is relatively expensive at about $ 9.99 (De Castro, Bissaco, Panccioni, Rodrigues, & Domingues, 2014).

2.8.6 Splash Math

Common Core Aligned Practice is ensured for fifth graders through most of these award winning applications which can be accessed from both mobile devices and home computers, which makes them quite universal approached. Naturally, the full version of the applications is paid and despite that the producers offer a free version, it rarely has the depth and efficiency of the full version. The app lacks an information section, about how to access and use all the features app (Mayer, 2003).

2.8.7 Little Monkey Apps Friends of Ten

Little Monkey Apps Friends of Ten is an example of a game type which introduces the numbers from 0 to 10 to children and makes them familiar with the operations regarding these numbers, including identifying of a number of objects without actually counting them or ways to pair objects so that they amount to certain number below or equal to 10. Such games are the foundation for establishing addition and subtraction skills. This application lacks the ability to save answers and graphs (Poobrasert & Gestubtim, 2013).

2.8.8 Hungry Fish

Hungry fish is a great academic game which is simple enough but at the same time very efficient in teaching the students to differentiate between the terms “equal to”, “greater than” and “lesser than”. There are so many glitches and bugs that need to be fixed, for example: once the child click the leader board you can't exit it, fishes eat the child without being touched and takes to child just 2 minutes to win (Gegner, Mackay, & Mayer, 2009).

2.8.9 Toot-Toot ABC

Toot-Toot Train teaches the addition and subtraction basics. despite the children can enjoy an introduction to the alphabet, numbers with a range of animals, but this App don’t have a lot of arithmetical operations that are important in the promotion of children's ability to deal with numbers and distinguishable. Thus, this app recommendation for children with age 1-3 years old (Poobrasert & Gestubtim, 2013).

2.8.10 Numbler

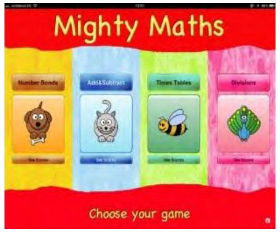
Numbler is another game used to help children get familiar with numbers and their real-life manifestation. This application is never designed to be used by the child himself without the supervision of a teacher or parent. This is a more general failure of this product (Poobrasert & Gestubtim, 2013).

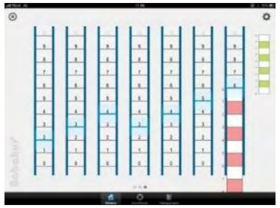
2.8.11 Pop Math

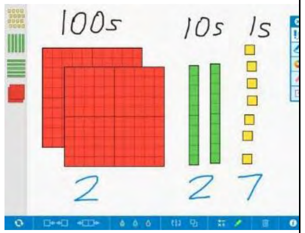
It is a fun application for children to practice basic mathematics: 6 pairs of bubbles with numbers float on the screen above beautiful backgrounds. This application does not allow the child to start at the level of preference. So, if he/she wants to start a higher level he/she must skip all previous levels and this may make the child feel bored in addition to wasting a lot of time (De Castro, Bissaco, Panccioni, Rodrigues, & Domingues, 2014).

Table 2.1 below presents the limitation of each mathematical application as mention in section 2.8.1 to section 2.8.11, based on the IxD dimension of form, content and behavior.

Table 2.1 Illustrate the list of Apps use to help children with Dyscalculia and number sense

Apps name	Apps Picher	Description	Limitations (IxD Dimension)
Mighty Math	 (https://itunes.apple.com/gb/app/mighty-maths/id515010700?mt=8).	Mighty Math. has been designed by primary teachers as an enjoyable way for children to increase their speed of recall of key number facts. The application contains four games which enable children to practice the following areas: -Number bonds to 10, 20 and 100; -Addition and subtraction of numbers up to 10 and up to 20; -Times tables (multiplication by all numbers from 1 to 10); -Division (by all numbers from 1 to 10). Each game is introduced by a different character and is brightly colour to make it visually stimulating. However, the numbers are clearly presented on the screen to ensure that children are not distracted from the mathematics. In each game, children can choose to complete as many questions as possible in one or two minutes, or they can play without a time limit.	**Form:** one of the shortcomings in terms of form, the buttons and the fonts are somewhat small. Which making difficult for children to distinguish buttons and fonts.
			Content: This application does not contain the important basics on how to write and pronounce numbers and distinguish them from each other, thus it is difficult to use for children age 3-5.
			Behavior: The game levels increase quickly which can be a little frustrating for children.

Babakus	 (http://www.skolappar.nu/babakus/).	The Babakus is a calculator that combines the best qualities of the western slide ruler with those of the eastern Abacus. It's part of a method for students with dyscalculia or math disability. You can easily work with addition, subtraction, multiplication and division using the Babakus.	**Form**: one of the shortcomings in terms of form, the App requires reading the manual to work out how it works. Therefore, the children will face difficulty in using it without supervision by parents or teachers. **Content**: This application ignores the basic mathematical skills which can be frustrating to fit each student's level of skill and understanding. **Behavior**: The game levels increase difficulty, the children will face difficulty in using it without supervision by parents or teachers.
Talking calculators	 (https://itunes.apple.com/us/app/talking-calculator/id424464284?mt=8).	A comprehensively featured calculator that has quickly become a favorite among adults and primary schools around the world. Designed for a wide range of users, this calculator has large colorful buttons, optional high contrast, full Voice Over support, and unique to this calculator; the option to use speech for answers, button names and formulas.	**Form**: There is a peculiar defect with the talking calculator function that prevents the full result from being spoken. The result of "Show Thousand Separators" won't be spoken, and instead only the portion in front of the first comma will be verbalized. **Content**: This application also ignores the basic mathematical skills which can be frustrating to fit each student's level of skill and understanding. **Behavior**: The app levels do not afford the children the advantage of practice in the underlying steps needed to perform the calculation. where, use of talking calculator results in the loss of instant recall of the basic addition, subtraction, multiplication, and division facts.

Number Pieces Basic	 (http://catalog.mathlearningcenter.org/apps/number-pieces).	Number Pieces Basic helps students develop a deeper understanding of place value while building their computation skills with multi-digit numbers. Students can use the number pieces to represent multi-digit numbers, count, regroup, add, and subtract. The drawing tools allow students to label representations and show their understanding.	**Form**: one of the shortcomings in terms of form, the navigate between buttons is complicated and inappropriate for children. **Content**: This application also ignores the basic mathematical skills. The children can use the number pieces basic just to represent numbers, add, and subtract. **Behavior**: The game levels have technical limitations, for example, when child wanted to write 50-86 and then switch to the blocks the child had to click on the calculator function to switch modes. thus, the children will face difficulty in using it.
Native Numbers	 (https://itunes.apple.com/us/app/native-numbers-complete-number/id570231808?mt=8).	Native Numbers is a fabulous app, promoting deeper learning and providing a much needed foundation in math for all children. The kids loved the gameplay feel of the app. This is a great app to help young kids learn the concept of numbers and basic math skills.	**Form**: **Content**: This application just presented the numbers from 1 to 9. **Behavior**: The disadvantage of Native Numbers apps is: automatically adjust up the level of challenge regardless of child's age or him/her ability. Children are required to demonstrate proficiency in each concept or skill before moving on to the next.

Splash Math	 (https://www.splashmath.com/apps/fifth-grade-math).	Splash Math Grade 5th app is a collection of fun and interactive math problems aligned to Common Core Standards. The app reinforces math concepts with self-paced and adaptive practice anytime, anywhere (works on iPhone, iPod, laptops and desktops).	**Form**: The app lacks an information section, about how to access and use all the features app. **Content**: **Behavior**: There are different difficulty levels including one figure addition & subtraction, one figure multiplication, division and two figure addition and subtraction.
Little Monkey Apps Friends of Ten	 (https://itunes.apple.com/au/app/friends-of-ten/id488573871?mt=8).	Little Monkey Apps Friends of Ten is an activity to be used in the early years of schooling to introduce an early understanding of numbers to ten, counting objects to ten, subtilizing - recognizing a collection of objects without counting them, counting on from a higher number, partitioning of objects and the combinations that make ten 8+2.	**Form**: The section that shows figures and numbers is a little confusing because they still try to make it add up to 10. **Content**: This application is foundation for establishing only the addition, subtraction and introduces the numbers from 0 to 10. **Behavior**: This application lacks the ability to save answers and graphs.

Hungry Fish	 (https://itunes.apple.com/us/app/motion-math-hungry-fish/id483049169?mt=8).	Hungry fish is a beautifully designed app that encourages mastery of basic addition and subtraction math facts and true number sense through a simple yet catchy game. You are given a fish that can only eat certain numbers at certain times. Very young children need only to match the correct number to the number on the fish. In more advanced levels children will need to add numbers together to make sure the fish can eat them (5=1+4, 2+3, 5+0). The most advanced levels include larger numbers, subtraction, negative numbers and a faster pace (-16= -4+-12, -9+-7 etc.). If you don't feed your fish, it gets smaller.	**Form**: one of the shortcomings in terms of form, the navigate between buttons is complicated for example: once the child click the leader board he/she can't exit it. **Content**: This application is foundation for establishing only the addition and subtraction. **Behavior**: This application takes to child just 2 minutes to win, which can be a little frustrating for children.
Toot-Toot ABC	 (https://play.google.com/store/apps/details?id=com.GamesLab.TootTootAbc).	Toot-Toot ABC is an interactive learning adventure where young children can enjoy an introduction to the alphabet, numbers and a range of wacky animals as they journey along with the Toot-Toot ABC. The game features 3 distinct modes, including an alphabet adventure, a counting adventure and finally an exciting train race. Kids can pick their favorite train to use with each mode, or give all three ago.	**Form**: The application has busy screen full of color and shapes and buttons, which confuses the child's attention. **Content**: This application doesn't have a lot of arithmetical operations that are important in the promotion of children's ability to deal with numbers and distinguishable. **Behavior**: The game levels increase quickly which can be a little frustrating for children.

Numbler	 (https://itunes.apple.com/us/app/numbler-math-game/id569515022?mt=8).	Numbler is great game for students to develop operations skills and algebraic thinking. Possible Classroom Uses: Students can play against the computer or against a friend, use the app to practice operations and algebraic thinking, connect the app to a projector, split the class/ group into two and play against each other.	**Form**: **Content**: This application focus on the equations while ignores the basic mathematical skills. **Behavior**: This is a more general failure of this application, it is never designed to be used by the child himself without the supervision of a teacher or parent.
Pop math	 (https://itunes.apple.com/us/app/pop-math-lite/id303258911?mt=8).	It is a fun way for kids to practice basic math: 6 pairs of bubbles with numbers float on the screen above beautiful backgrounds.	**Form**: one of the shortcomings in terms of form, the fonts are somewhat small. **Content**: This application focus on the addition, while ignores the basic mathematical skills. **Behavior**: This application does not allow the child to start at the level of preference. So, if he/she wants to start a higher level he/she must skip all previous levels and this may make the child feel bored in addition to wasting a lot of time.

2.9 Summary

As a conclusion, this chapter is explained the substantial increase in prevalence rates for Dyscalculia and low numeracy over the last years has sparked debate regarding cause and critical need for effective services. Also, this chapter is explained the basic concepts that related and can applied to help Dyscalculia and low numeracy children with number sense especially in education field in order to design a more effective and attractive educational game application. It also has reviews some related literature about assistive technology and mobile applications with the highlight at some of the existing apps, as a platform to help in the design of educational game app to improve the mathematical skills for Dyscalculia and low numeracy children. To increase the probability of successful learning in Dyscalculia and low numeracy children, the app design for these children will need to meet a set of design principles. These principles based on Interaction Design (IxD), can be implemented to help through this development process.

CHAPTER THREE
RESEARH METHODOLOGY

3.1 Introduction

In the previous chapter, the literature discussion was on Apps that helped children with Dyscalculia and low numeracy in understanding number sense. This chapter will cover the research methodology. The methodologies employed in this research were not merely for the sake of collecting data but was systematically designed to provide solutions to the problems (Kothari, 1990; Kumar & Phrommathed, 2005; Kumar, 2005). In addition, this chapter will discuss in more details the methodologies adopted in achieving the goals mentioned in Chapter one.

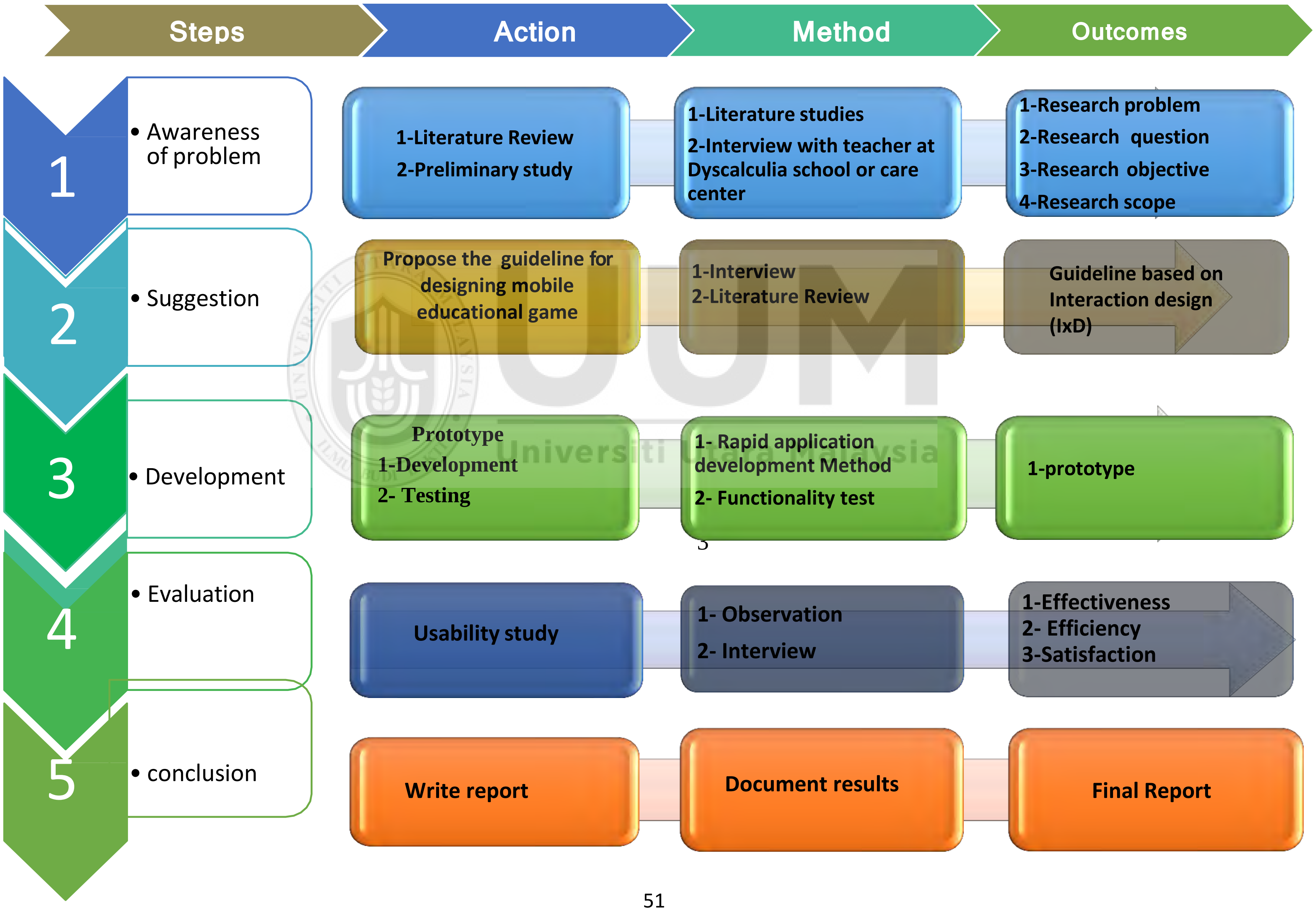
The methodologies seek to build and estimate the IT artefacts in order to meet the human needs and pay particular attention to the process of constructing artefacts instead of the design of the final product (Vaishnavi & Kuechler, 2007). This research was divided into five phases with each individual phase contributing towards specified objectives. These phases are awareness of the problem, suggestions, development, evaluation and conclusion.

3.2 Research Procedure

The design starts off with an awareness of the problem. Here, existing knowledge is used to provide remedies and solutions. After this, a trial run is made for the artefacts implementation which relied on the solutions that were suggested beforehand. This phase of the research is called the development stage.

The implicit and explicit suggestions from the functional characteristics will be used to evaluate the implementations to see if they are partially or fully successful. In general, the aim research process is repeatedly to achieve all of the development, evaluation and the suggestions. The final research design specifics will be summarized in the conclusion. The study's comprehensive research design is shown in which is dependent on the design methodology.

Figure 3.1. The research procedure



3.2.1 Awareness of Problem

The initial stage of the methodology involves comprehending the research scope and the objectives. The necessary information was obtained from reading the certain books and journals. During this phase, preliminary information sourcing was carried out to gather information about the children with Dyscalculia, low numeracy and number sense, as well as the existing mobile Apps that are designed to help these cases.

These important facts give insights to current approaches employed by teachers to inculcate number sense awareness among children. The preliminary study involved an interview with three teachers to capture their information about children with number sense's requirements which can be done through design educational game to improve number sense learning. Thus, the data were collected in order to obtain more information regarding the main issue of the research. This was done by conducting a literature review and a preliminary study.

3.2.1.1 Literature Review

The literature review technique complements the information that is collected from primary sources (Kumar, 2005). The literature reviews significant in all studies due to the fact that they are a good source of knowledge and the pure evidence presented by them facilitates an easy research (Patton, 2002). The literature review can be categorized into journals, conference proceedings, websites, books and other documents related to the topic of interest (Shittu & Jaleel, 2009).

3.2.1.2 Data Collection

The initial study entailed the arrangement of interviews (Huda Wahida, 2013; Hoffer, George & Valacich, 1999) as collecting data about the needs of users can be done by means such as one-to-one interviews. The study encompassed personal interaction with three teachers at Sekolah Kebangsaan Mergong, Alor Setar, Kedah, Malaysia (see Figure 3.2). The teachers were posed a few open-ended questions obtained from a source relevant for this task (Patton, 2002; Posner, 2008; Kuhl, 2014). Such an interview actually helps the investigator ask questions over and above those based on the theme of the research; moreover, questions as these aid in looking at the subject of research from diverse points of view. The participants' responses were recorded with an iPhone Recorder device and with their due consent (Cohen & Crabtree, 2006). The method of gathering data is as depicted in Appendix A. The questions used were modified from Patton (2002) Posner (2008), Kuhl (2014).

Figure 3.2. Teachers interview for data collection.

Besides, the questions concerned the experience of the participants in teaching suspected dyscalculia and low numeracy children, and on how well they could use technology to sharpen the abilities of these children. Prior to the study, the interviews helped in obtaining valuable information (Wildemuth, 2009). The main advantages of the interviews were to back up the qualitative information gathered earlier, to help in identifying difficulties requiring the greatest attention, and to recognise critical elements in devising a game model for low numeracy children with number sense problem (Kaur, 2006).

3.2.2 Suggestions

The implementation of these activities will facilitate in making adequate suggestions; furthermore, some related works mentioned in the literature will be carried out in order to elaborately comprehend some successful apps. The guiding principles for many decisions were from existing Apps especially those found in Chapter 2. Analysis of existing apps will be carried out to indicate appropriate design principles of number sense in educational games for children with Dyscalculia and low numeracy. At this point, the study achieves Objective1.

3.2.3 Development

The development stage includes the development and implementation of the prototype. The design occurs first whereby at this point the main task is to make sure that the functions exist in a good arrangement with good case, active, sequence, class and state diagrams under the correct category of artifacts. A database design will be added for refinement.

This study makes use of Rapid Application Development methodology (RAD) to develop the model. Rapid application development is a software development methodology that includes iterative development and software prototyping. According to Whitten (2004), it is a merger of various structured techniques, especially data-driven Information Engineering, with prototyping techniques to accelerate software systems development (Whitten, Jeffrey, Bentley, & Dittman, 2004).

Structured techniques and prototyping are often used in rapid application development, to define users' requirements and design the final system. The development process kicks off with the development of initial data and business process models using structured techniques. In the next stage, requirements are verified using prototyping to refine the data and process models. These stages are repeated iteratively; further development results in "a combined business requirements and technical design statement to be used for constructing new systems" (Whitten et al., 2004).

The prototype mentioned in this study requires conditions as indicated in the Table 3.1, which facilitates the work and enables interaction with the users. In our study, we will refer to apps that make use of Android platforms (Simm, Ferrario, Gradinar, & Whittle, 2014), which is an operating system often employed on mobile devices like smart phones and tablets. Lastly, the providers of the content will create a custom interface to store and retrieve different kinds of data stores like SQL databases (Abdulwahid, 2015). Eclipse is classified as an open source software development environment. Eclipse was written in Java for the development of apps in the same Java language and environment.

Eclipse is a safe environment that we can incorporate many projects and allows for many files to be included in the project. At this point, our study would have met Objective 2, which was to design and develop a mobile educational game for dyscalculia and low numeracy children. This prototype is named 123GO

Table 3.1: Prototype Development Environment.

Prototype Development Environment	
Program language	Eclipse tool for Java language
Operating System	Android platform
Database	SQLite
Deployment	Play store

3.2.4 The Evaluation Method

The phase of assessment involves the adoption of a functionality test and a usability test, as these necessitate users to make use of the product (Taheri, Alemi, Meghdari, PourEtemad, & Basiri, 2014). Usability is an important characteristic of a product. According to Nielsen (1994), usable systems are often easy to learn, efficient, not prone to error, and provide satisfactory service, thus helping to increase productivity, reduce costs, and improve user satisfaction. Usability testing is an evaluation method for measuring how well users can use a specific software system. The test moderator assigns pre-decided tasks, singly, to test users who, on their part, execute these with the interface provided to them (Daradkeh, 2010; Nielsen, 1994).

The efficacy of the app was simultaneously evaluated by an assessment of its functionality and usability. Before this phase is complete a qualitative analysis will be used to evaluate the results of the prototype usability test for the purpose of promoting the App use among dyscalculia and low numeracy children. By this point, objective three of the study had been accomplished.

3.2.4.1 The Functionality Test Method

The functional methodology typically includes the functional testing, aimed at evaluating the quality of the prototype process, which takes into consideration the specifications of the prototype component in question (Kaner & Falk, 1999). The method of test functionality allowed gathering the information on the prototype functionality from users' feedback. The main goal of using functionality tests was to guarantee proper functioning of the prototype. The developer of the prototype was responsible for conducting the tests.

3.2.4.2 The Usability Test Method

The results of the usability test reveal the quality of the product (Tahrina, 2012). As it was pointed out in Nielsen (1994), applicable systems do not require substantial training, but the effectiveness, efficiency and satisfaction of these systems can be high. Usability testing can be used for measuring the user-friendliness of software. By using the criteria of effectiveness, efficacy, and satisfaction, this test collects non-biased data on how well the end users can access the content of the application or run it on mobile or other devices.

A usability test can be considered as effectiveness, provided its results clearly demonstrate whether users can use the application freely, whether they enjoy using it and if the application helps users improve their performance (Nayebi, Desharnais, & Abran, 2012; Wang, Ofsdahl, & Morch-Storstein, 2008). At the same time, an efficacy usability test should measure whether the application is useful for doing a certain task. Furthermore, the satisfaction usability test should provide the information on the users' attitudes towards the prototype functioning (Thompson, McClure, & Jaeger, 2003). The usability test can be conducted in many ways based on the data collection and data analysis methods. For example, Adil (2015), conducted the usability test by means of interviews with total of 10 teachers as well as doing the questionnaires with 5 autistic children between the ages of 5 to 7 years.

Al-Wakeel, Al-Ghanim, Al-Zeer and Al-Nafjan (2015), conducted the usability test into three main parts. The first part was based on the Eye Tracking usability measurement tool; second part was based on observation and the third part was depended on questionnaires with a sample of 14 children, 8 autistics and 6 non-autistic children. The second part also divided into two sections: the first section depended on manual observation when used an eye tracker as measurement tool and second section was automatic observation using Morae usability-testing software. In additional, Ismail, Diah, Ahmad, Kamal, & Dahari (2011), conducted the usability test by means of interviews and questionnaires with total of 5 children two of them were five years old and another three were six years old. According to Ismail, Diah, Ahmad, Kamal, & Dahari (2011), the usability tests involved in this study were conducted by means of observation and interviews.

The participants of this usability study included three teachers and five children with number sense problem aged 7-9 years old from Sekolah Kebangsaan Mergong at Alor Setar, Malaysia, (Skiada, Soroniati, Gardeli, & Zissis, 2014; Ribeiro, Araujo, & Raposo, 2014). At this stage, the study had accomplished objective three.

3.3 The Procedure

The observation and interview method is applied in this study. The first method that was deployed to test the purpose of usability was the interview approach. To magnify the supporting data and raise the chances of precision of the given data regarding the usability of the app (Gunduz & Pathan, 2013; Frauenberger, Good, & Keay-Bright, 2011), an interview was conducted with teachers at Sekolah Kebangsaan Mergong at Alor Setar, Kedah, Malaysia. Figure 3.3 below provides sample of interview question and questionnaires (Ismail, Diah, Ahmad, Kamal, & Dahari,2011).

Screen / Evaluation element	Child 1	Child 2	Child 3	Child 4	Child 5
The child do not have trouble to navigate using keyboard					
The child do not have trouble to find the start menu					
Graphics used on the page attract the child					
Music used attract the child					
Size of the game window opened is good enough					

Figure 3.3. The sample of observation item.

With the help of an interview guide, open-ended questions were put up to the teachers that enabled the researcher to ask extra questions that were not mentioned in the interview protocol (Figure 3.4). An iPhone device was used to record these interviews. The information collected from the teachers was recorded after taking their consent (Cohen & Crabtree, 2006). Teachers were asked about the pre-requisites that should be conformed to help the kids with number sensing so as to get their feedbacks that would be used in application designing. The response that was generated in this interview will help the researchers to ballpark the teachers' responses to this app. Furthermore, it would offer valuable data pertaining to the prototype and its impact on the kids. The next method used for the purpose of usability testing was the observation method. The 123GO app was installed in a Samsung Galaxy Grand Gt-19082 mobile device model, with an Android operating system version 4.2.2. The teachers were instructed to help the children on how to use the 123GO app accurately (see Figure 3.5).

The teacher and the children sat with each other, and the latter was offered total control of the device (Figure 3.6). The researcher was required to visit the school few times within a period of two weeks. At least 10–15 minutes were allocated to each child to use the application (Hussain, Mutalib, & Zainol, 2014; Dehkordi & Rias, 2014). The researcher noted the kids' interaction with the 123GO app during the given time frame. The observation was taken from Patton, (2002), Posner, (2008), Kuhl, (2014), Ismail, Diah, Ahmad, Kamal, & Dahari, (2011). The observation time took an average of 10–15 minutes. This was the average time needed by each child to use the app and completed the task. Gunduz and Pathan (2013), stated that an observation is simple and efficient method to acquire data when conducting scientific studies.

The participants' responses were recorded from Sekolah Kebangsaan Mergong at Alor Setar, Kedah, Malaysia, once all the observations were completed. This testing's usability metrics were focused on the efficiency, efficacy, and satisfaction specified by the standard of International Organization for Standardization which is ISO 9241-11. ISO guidelines were adopted to conduct an analysis of the data (Ismail, Diah, Ahmad, Kamal, & Dahari,2011; Abdalha et al., 2014; Rabail & Fahim, 2014; Khairul & Zamhar, 2015; Rabail & Fahim, 2014). All data collection was conducted through methods of observation and interview. Chapter five discusses all the gathered data and results.

Figure 3.4. Teachers being given instructions on the use of the 123GO App

Figure 3.5. The teacher being given instructions on how to use the new App

Figure 3.6. One of the participants interacting with 123GO App

3.4 Sampling

Observations and interviews were used in order to conduct the usability tests involved in this study. In 2000, Jacob Nielsen, who is one of the gurus in IxD stated that small sample sizes are beneficial because of the ease of gaining the return on investment (Nielsen, 2000). This is due to the fact that each additional study participant tends to increase the testing costs. Thus, for the usability test, the study chose five children with number sense aged of 7 to 9 years from SK Mergong at Alor Setar, Kedah, Malaysia (Nielsen, 2000; Marina, Norizan, Nor Ashikin, and Mohd, 2011). Moreover, the researcher conducted the interview with three teachers at Sekolah Kebangsaan Mergong at Alor Setar, Kedah, Malaysia (Chien, Jheng, Tang, Tseng, & Chen, 2015).

3.5 Data Collection and Analysis

The interview results and the observation data were used as bases for the data that were gathered for this study. Participants were first asked to use the 123GO app. Afterwards, the data were obtained through observations and interviews with the teachers at the number sense school. This was done in order to evaluate how much they understood and to see how they perceived the 123GO app. The data gathered were then utilised to conduct the analysis. During the testing, the children were free to use the tool to perform the exercises. To complete the task, each child had 10–15 minutes.

The observer observed and evaluated the children's efficiency and effectiveness based on the task list (Ismail, Diah, Ahmad, Kamal, & Dahari,2011). 'Yes' will be written to represent a task that was successfully completed. 'No' will be used to represent a task that was not completed, while 'Partial' will be used when the evaluator sees it fair to give some mark for an unsuccessful task instead of just writing down 'No'. The researcher interviews the children after the completion of the observation process. The questions were taken and adopted from Ismail, Diah, Ahmad, Kamal, & Dahari, (2011).

3.6 Analysis Techniques

The following steps make up the data analysis process;

Step 1: Complete observation and gathering of data based on efficiency, efficacy, and satisfaction.

Step 2: Preparing the summary table for efficiency, effectiveness, and satisfaction.

Step 3: Calculating the efficacy and efficiency rating according to Ismail, Diah, Ahmad, Kamal, and Dahari (2011). This can also be seen below:

Effectiveness (%) = (Yes = (Partial x 0.5)) / Total x 100%

Efficiency (%) = (Yes = (Partial x 0.5)) / Total x 100%

Step 4: Calculating the satisfaction value based on the formula below (Ismail, Diah, Ahmad, Kamal, & Dahari,2011).

Satisfaction (%) = Answer Point / Total Point x 100%

Step 5: Calculation of the usability rating will finally be done and computed based on the following formula (Ismail, Diah, Ahmad, Kamal, & Dahari,2011).

Usability (%) = (Effectiveness + Efficiency + Satisfaction) / 3 x 100%.

The objective of this project will be summarised by the result. Doing this involves measuring the usability of the 123GO in challenging the number sense learning of the children involved.

3.7 Summary

The methodology used in this study is thoroughly outlined in this chapter. The methodology of the study has five stages, and every stage involves activities and output. The objectives presented in Chapter one are reflected here. Additionally, the data collection method through interview and literature review is also presented. Having discussed the methodology, the following chapter will describe the analysis method used in evaluating the existing apps that were discussed in Chapter two. This is done so that the best design principle based on interaction design (IxD) can be identified and applied for an educational game app on number sense learning and that can be used by children that have difficulties with low numeracy and thus number sense problem.

CHAPTER FOUR

PROTOTYPE DEVELOPMENT

4.1 Introduction

This chapter shows the development steps of 123GO mobile application. It has listed the functional and non-functional requirements. Additionally, this chapter presents the description of the prototype's functions with user interface design as suggested by the proposed guideline. The application is working under Android environment. Java programming language has been used for implementing this application, as well as Adobe Photoshop CC application for design and graphic purpose.

4.2 The Guidelines of App Educational Game for Dyscalculia and Low Numeracy Children

From the previous studies, this study has put forward proposed guidelines for designing of a new educational game based on IxD. These guidelines, which will combine the benefits from previous application, thus avoiding their existing issues, likewise made a number of design decisions to provide an app which better fits the target group's needs. The following Table 4.1 shows the guidelines of this study about propose i.e. design of a new educational game for children with dyscalculia and low numeracy based on IxD.

Table 4.1: The IxD guidelines with respect to three IxD dimensions and their elements

Dimension	Element	Proposed Style	Author
FORM	1. User Interface	Interfaces are designed to be easy, and without major visual effects for purpose of non-dispersion the possibility of focus, to maximize the understanding and learning of the children	Cooper, Reimann, and Cronin (2007).
	2. Icon	There must be a reasonable number of icons in each page .And it can be easily observed	Lyan. Amjad, Shaden, and Khalid (2015). Bodine and Hutchison (2014).
	3. Screen	The screen must be clean and tidy, and focus to the assignment	Aziz and Husni (2012).
	4. Color	Children aged between seven and fourteen years old prefer extreme colors (e.g. blue, red, green, yellow)	Naranjo-Bock (2011).
	5. Font	Be easy to read font. Size 12-14 points	Aziz and Husni (2012).
CONTENT	6. Audio	Audio should be presented together (at the same time as the numbers).	Lyan. Amjad, Shaden, and Khalid, 2015; Bodine and Hutchison (2014) Ribeiro et al. (2014).
	7. Language	The application must use the local language of the country or another global language or language to be learn.	Poobrasert and Gestubtim, 2013.
	8. Pronunciation	The pronunciation of numbers should be clear and precise.	Lyan, Amjad, Shaden, and Khalid (2015).
	9. Graphics	Use graphic, images, photos to increase their understanding and illustrate meaning.	Aziz and Husni (2012).
BEHAVIOUR	10. Navigation	Simple and easy navigation	Aziz and Husni (2012).
	11. Simplicity	As the number of choices increases, so does the effort required to collect information and make good decisions. Features can be an exhausting disease for users.	Hoa (2015).

4.3The Language Page of 123GO mobile application:

Essentially, a 123GO mobile application has been released with two different languages which are Malay and English language. Malaysian language is a default language for the application's appearance. The 123GO application provides an interface with the couple of choices for presenting language. Hence, the users can switch between the languages by selecting a specific language and press on "Select" button from this page. The application will respond to users' activity and display the home page with selected language. Figure 4.1 shows the interface language page with both of application languages.

Figure 4.1. the interface of 123GO App with both of application

4.3.1 Home Page

The home page of 123GO mobile application is a main gate to use the functions of this application. 123GO mobile application has three core functions which represents the levels of mathematic learning. These functions are display in English language by: Beginner function, Intermediate function and Advance function, at the same time they display in Malay language by: Mudah, Sederhana and Sukar. The actor can deal with every function of application by pressing on its icon thus, the application displays the page of selected function. In the end, the main home page has a home icon when the actor pushing it return to the page language. The following figure 4.2 shows the home page of 123GO mobile application**.**

Figure 4.2. The home page of (123Go) mobile application

4.3.1.1 Beginner Function

The beginner function is a first level of learning for this application. This level deal with teaching a child the fundamental skills of numbers, which is counting, writing and pronunciation the numbers. This is done through the use of colours and integrated audio-effects. The beginner function starts by pressing on level one icon. As a consequence, the application displays the page of level one of learning which has three icons which are: Listening icon, Write icon and Home page icon.

1. **Listening icon:** when the actor press on this icon the application displays the picture of number with four buttons which are: Pronunciation button, Next arrow button, Back arrow button and Home page button. When the user press on pronunciation button, the application plays an audio of Pronunciation for appeared number on screen with selected language. Also, the user utilizes arrow buttons (Next, Back) to move among the pictures of numbers. in addition, the user utilizes Home page button to return to the beginner page. Figure 4.3 shows the picture of number with four buttons.
2. **Writing icon:** when the user press on this icon the application displays a learning video to teach a child how to write the numbers. Figure 4.4, 4.5 shows a learning video.
3. **Home icon**: the user utilizes this icon to return to the beginner page.

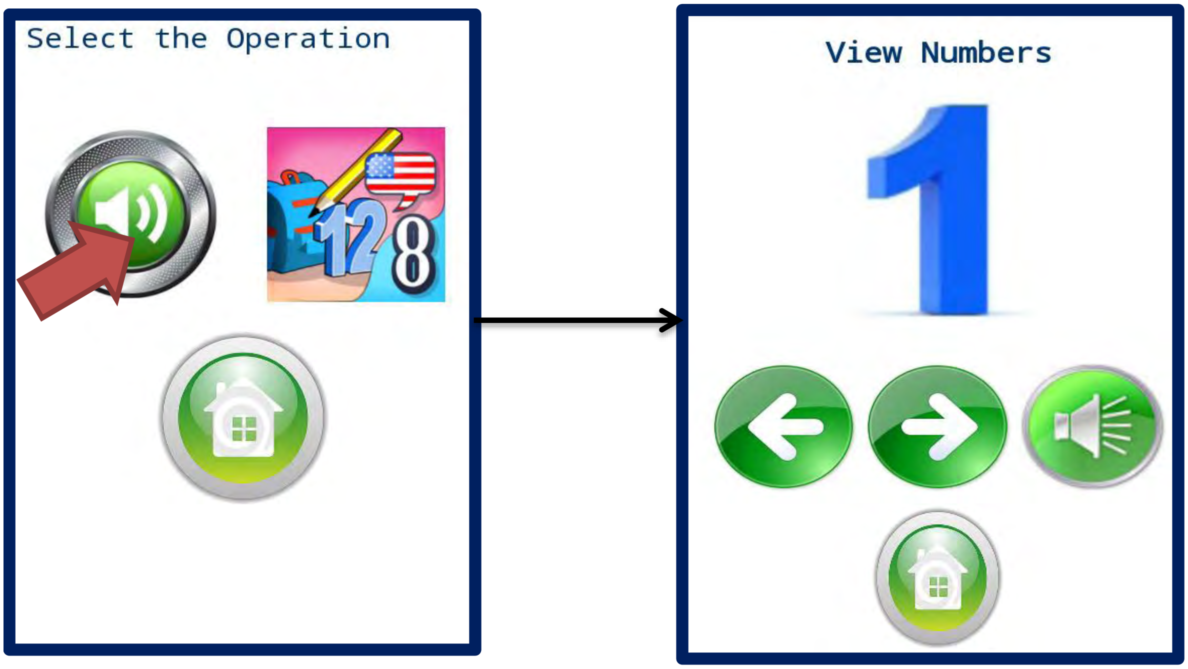


Figure 4.3. The Listening icon with for buttons

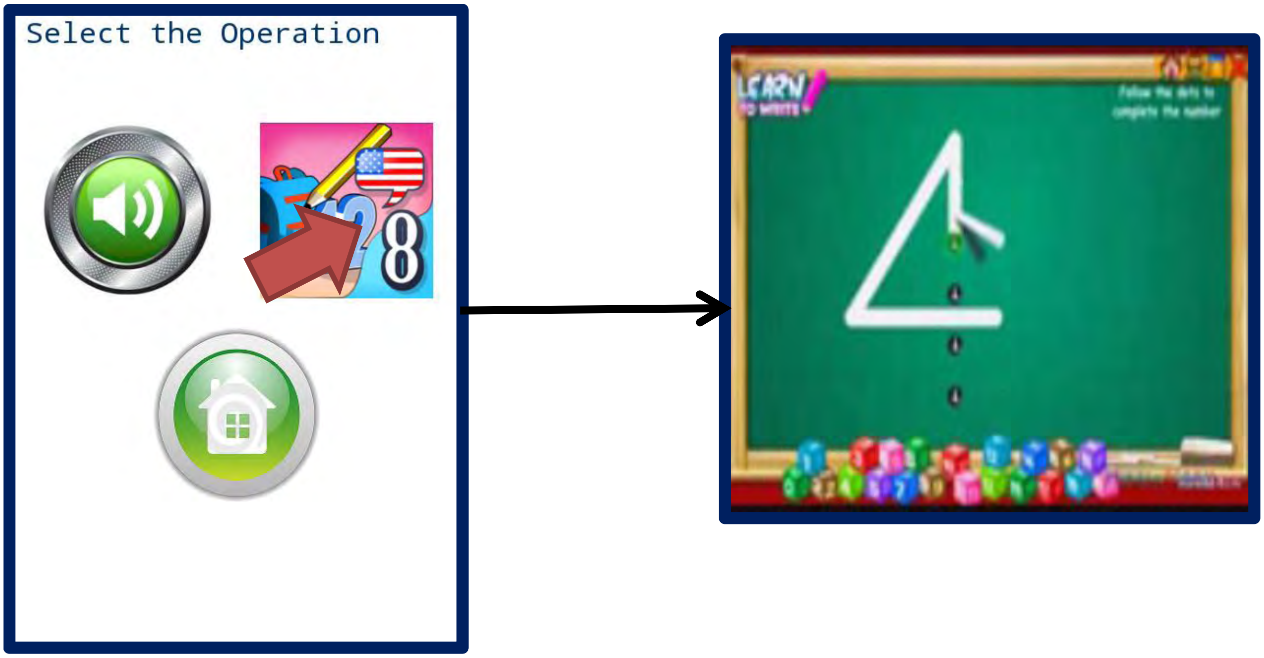


Figure 4.4. Writing icon for the learning video

Figure 4.5. Writing icon for the learning video

4.3.1.2 Intermediate Functions

The second function of 123GO mobile application develops to teach a child the value place of numbers for example, maximum and minimum moreover arranging the numbers in ascending and descending order (number after and number before). This level has been named as "Intermediate Functions". The user press on the one of operation icons in order to begin learning these functions. However, the application displays the Intermediate Functions page when the user selected level two from beginner function page. The Intermediate Function page contents five buttons which are: Min button, Max button, number after button, number before button and home button.

1. **Min or Max buttons:** content two pictures of numbers and arrows icons to move to another questions. The actor selected the correct answer by pressing on the correct answer icon and then the application checks the answer and display a message of results.
2. **Number after or Number before buttons:** when the actor utilizes these buttons the application displays a series of three numbers with a lost number. Additionally, it displays a three options of answer and arrows icons to move to another questions. The user selected the correct answer by pressing on the right answer and then and then the application responds to answer and display the message of result.
3. **Home button:** the actor can go back to home page by click on Home button.

The figures 4.6, 4.7, 4.8 below show the details of this function.

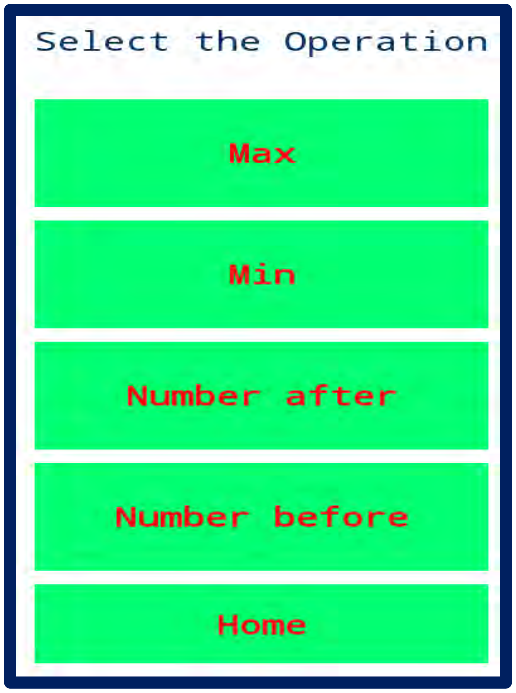


Figure 4.6. The Intermediate Functions level

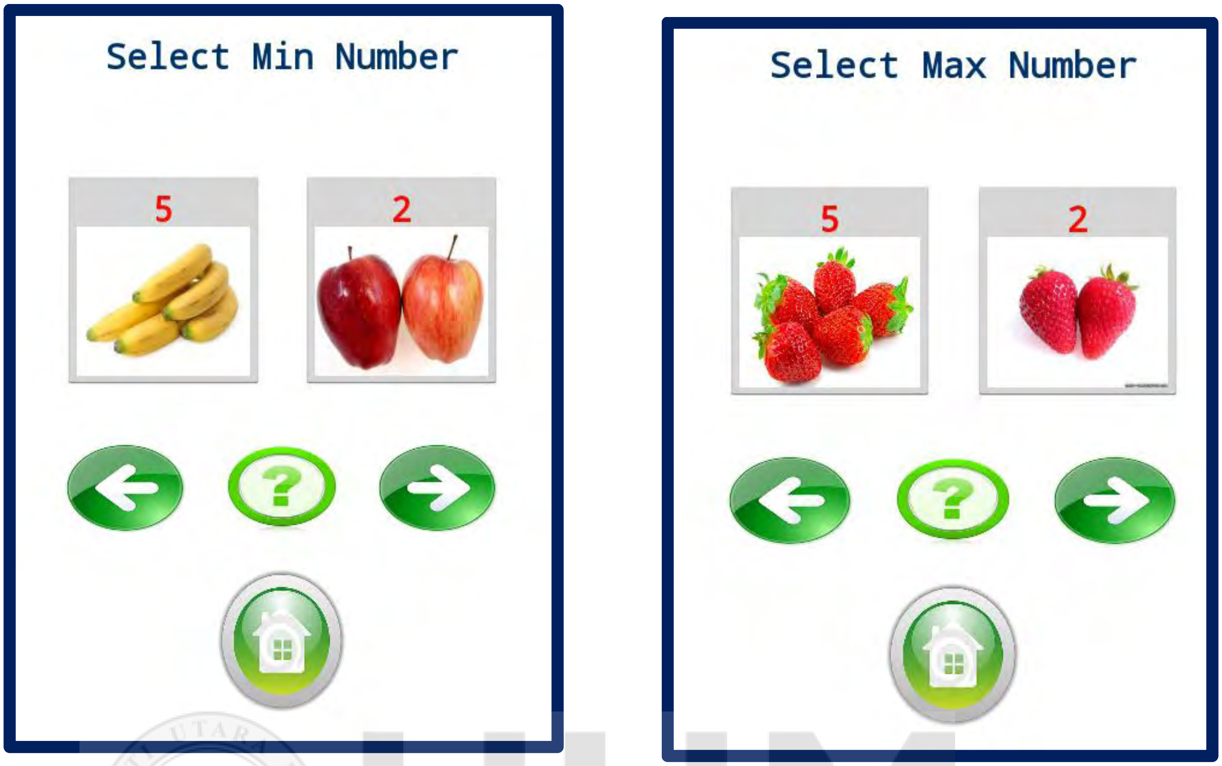


Figure 4.7. The Min or Max icon buttons

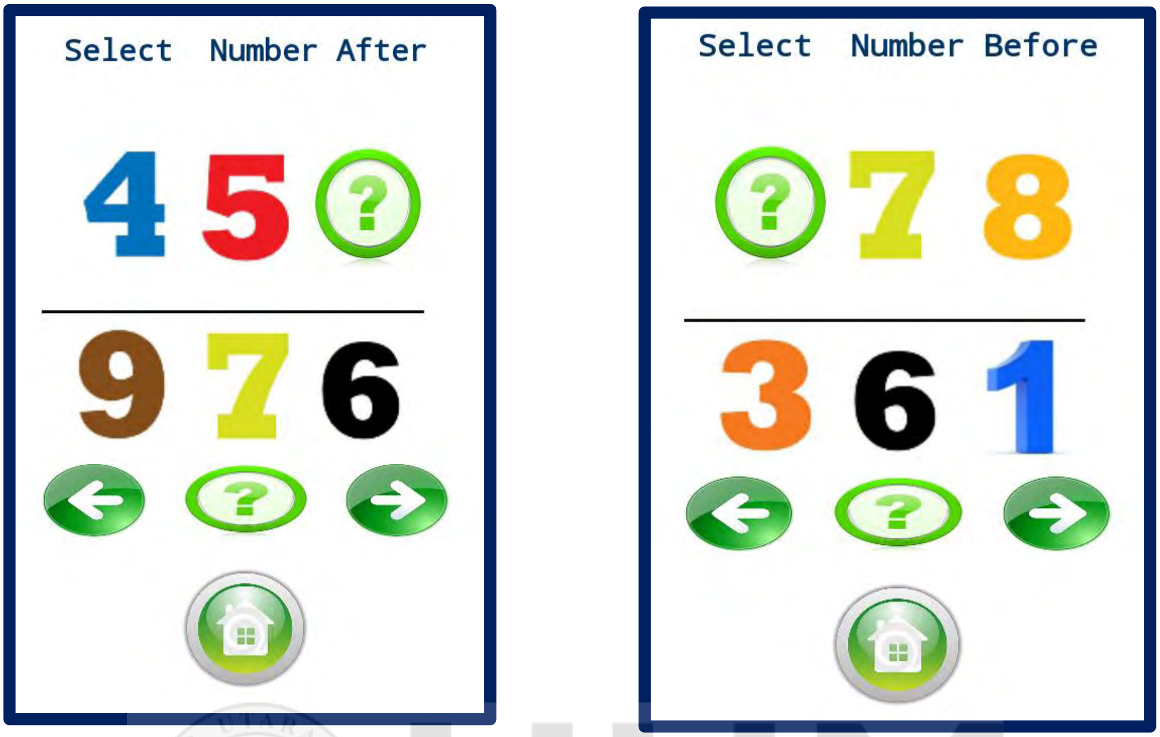


Figure 4.8. The Number after or Number before icon buttons

4.3.1.3 Advance Functions

The final function of 123GO mobile application which represent third level of learning for this application called Advance Functions. It focuses on teaching a child the main operations of mathematics such as: addition, subtraction, multiplication and division. The main page of this level has five icon buttons which are: addition button, minus button, multiplication button, division button as well as the home icon button.

1. **Addition, Minus, Multiplication or Division buttons**: The application begin to teach a child these operations when he/she chose one of the operation icon button. The application shows the user interface of selected operation which consists of the question about selected operation with three answer choices. In addition, the user interface of selected operation contents four icon buttons which are: Next arrow button, Back arrow button, question button and home button. By the way, the user interface of every operation in this level is almost same. The user selects the right answer of appeared question and press on the question icon to approve the answer. The application plays an audio message about correctness of choice if true or not. In addition, the users press on Next or Back arrow buttons to go among the other questions of selected operation.
2. **Home button:** the user can go back to home page by click on "Home" button.

The figures (4.9, 4.10, 4.11) bellow shows the details of this use case.

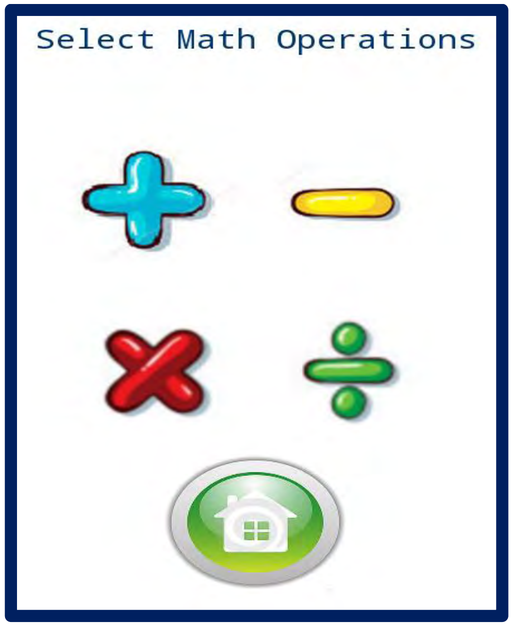


Figure 4.9. The Advance Functions level

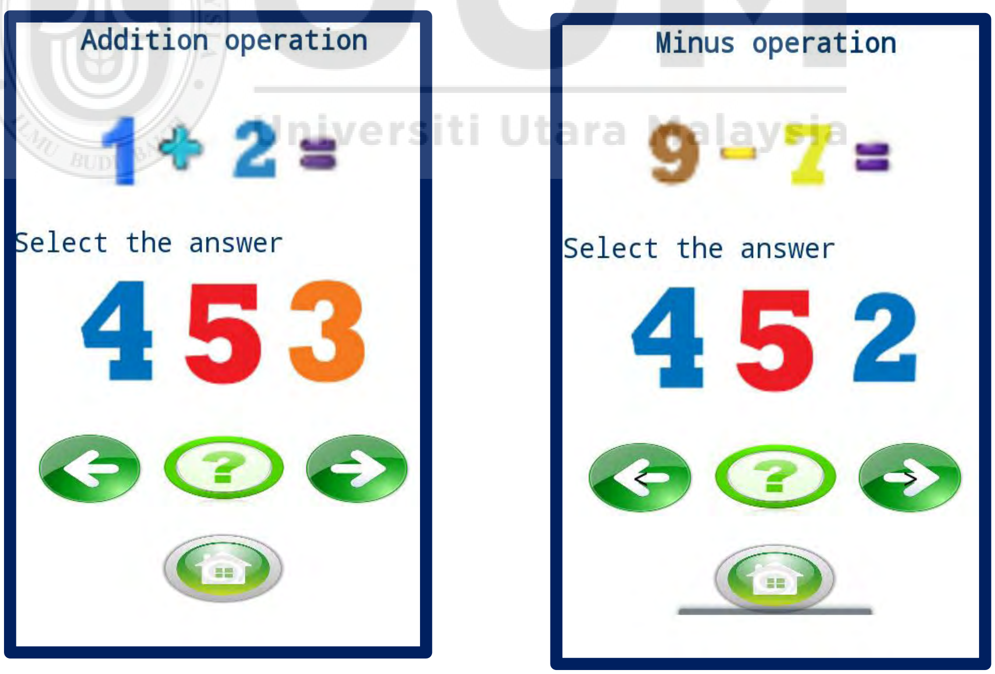


Figure 4.10. The Addition and Minus operation levels

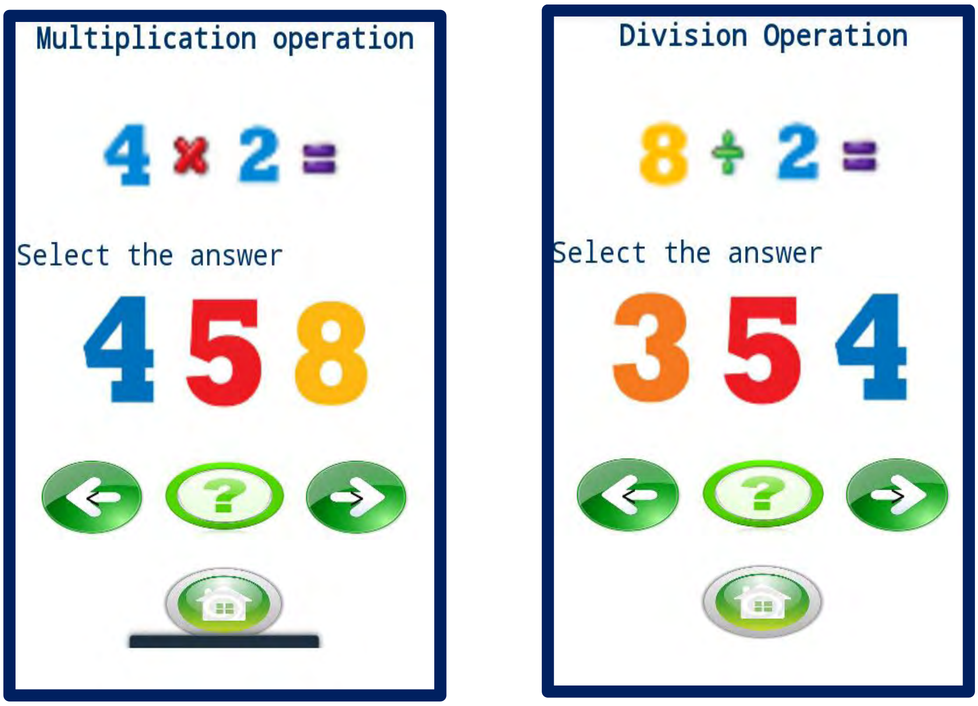


Figure 4.11. The Multiplication and Division operation levels

4.4 Summary

This chapter begins with an emphasis on the app 123GO requirements. Both are set functional requirements and non-functional. This chapter reviews explain the prototype's interfaces and how to use it, as well as explain the levels of the prototype. Having designed the App, a prototype has been developed to help Dyscalculia and low numeracy children to enhance their mathematical skills.

CHAPTER FIVE
EVALUTION

5.1 Introduction

This chapter also discusses the evaluation of the 123GO app. Thus, achieving the study's third objective. As outlined in Chapter 3, usability and functionality tests were conducted in order to determine the usability of the 123GO app (Nielsen, 1994). Data gathering was done through observations and interviews. Discussion of the results was then done. The functionality test is an important step in making sure that the app is working as expected. This is done before its usability is tested in order to ensure that users will also have a good experience while trying out the app. To determine all the 123GO app's functions, a functionality test was conducted using the test case method. There is also an explanation of the testing process and a discussion of the results. The usability test had varying procedures. These procedures are described in detail in the following paragraphs. The evaluation is normally focus on the design of and therefore not on measuring performance of the children

5.2 Evaluation Procedure

The procedures for the usability test vary. The subsequent paragraphs explain these procedures in detail.

5.2.1 Functionality Test

The functionality test is a very important stage during the software development cycle. Each case ends with the process of evaluation and verification, a step that eliminates all the errors. The testing's primary goal is identifying and removing most of the system errors and forming a test suite that includes several test cases that were done during the maintenance phase. System errors are normally found in the system during different stages (Hussain, Jomhari, Kamal, & Mohamad, 2014).

Therefore, in order to check for errors during these different phases, there should be testing at various levels. The developer of the 123GO implemented the functionality test. Testing was done for every function of the prototype. Questions about the 123GO app's functionality were posed to the teachers. Appendix B described the result of functionality test.

5.2.2 Usability Test

The usability test methods used in this study involved interviews and observations. Based on the design principles and requirements described in Chapter 4, a usability test was done to make sure that children find the 123GO app useful and easy to use. The interview method was done at Sekolah Kebangsaan Mergong, Alor Setar, Kedah, Malaysia, and it involved three teachers who are dealing with low numeracy children and received proper training from the ministry. To increase the supporting information and increase the accuracy of the usability data of the app, the study was supported and supplemented by interviews. Therefore, by using the interview method, usefulness and ease of use of the 123GO app were collected in the views of teachers. Consequently, the observation method involved a sample of five children taken from Sekolah Kebangsaan Mergong, Alor Setar, Kedah, Malaysia.

5.3 The Results

This section shows the results that highlight the data and results gathered from the test cases and the usability testing. Based on the results, separate discussions were conducted. Descriptions for the results from the test cases were given first, followed by the usability test results.

5.3.1 Results of Usability Test

As previously mentioned, the usability test method in this study involved interview and observation. Therefore, the result from the usability test starts with the interview method. The results gathered from the observation method are presented next.

5.3.1.1 Results of Teacher's Interview

This section discusses the results from the researcher's interview with the teachers. The focus of the interview questions was on the teachers' perceptions on the requirements that the application has to meet in order to help the children with number sense, and gather feedbacks that can then be used within the application design. Each teacher had to answer five interview questions. The results and discussions from the three respondents are summarised in the following points:

i. The first interview question was: "How effective is the 123GO app in educating the children with number sense problem? All the teachers responded positively and gave good feedback about the efficacy of the app in educating children with dyscalculia. Each of the teachers also said they observed a growth in the learning ability and potential of the children despite each child having different learning curves.

ii. The second interview question was: “From your perspective, how was she/he satisfied with the app?” The respondents stated that the children used their facial expressions to show their happiness. They were observed to be holding their smart phones and trying to use it again and again. The children found the 123GO app to be appealing, and they enjoyed clicking on the pictures on the tablet’s screen through the interface of the 123GO app. Furthermore, they observed that the children paid attention to the interface's voice feedback as it was repeating the words of numbers.

iii. The third interview question was: “Describe any special responses exhibited by the children while using 123GO and the circumstances at that time.” All the teachers stated the children enjoyed listening to the voices and clicking on the pictures.

iv. The fourth interview question was: “Do you feel that using 123GO's primary function consists of education, entertainment, or both? Why and how?” All of the teachers answered "Both". They gave this answer because they all believe that the app is a teaching-assistant tablet app that teaches children number sense and improves their cognitive mathematical skills and entertaining. Moreover, the app does not only help the children improve their disability but it also helps in measuring their progress using the assignment category.

v. The fifth interview question was: “Do you think that the size of the device is appropriate for the 123GO app?” All the respondents were in favour of using a Samsung-sized device because its screen size is appropriate for the 123GO app.

vi. The interviews conducted with the teachers showed how excited they were about the 123GO app. They were also particularly excited about its content. They suggested improving the colours in order to make it more interesting. The app was also perceived to be more interesting if it incorporated an illustrative picture. Furthermore, the number sense children thought that the 123GO app was simple and easy to use. Additionally, the app helped the children understand and memorise the numbers for longer periods of time. Given this positive feedbacks, the teachers expressed hope for the 123GO app being used in schools and at home by the children, and even by their parents as they guide their children.

vii. The results of the interview revealed that the 123GO app was very effective in teaching subjects and giving important contributions like lessening the burden of teaching and production for caregivers, and even increasing the learning motivation and improving the children's ability to identify mathematical skills. Moreover, it was discovered that integrating mobile technology into traditional teaching fostered a learning environment that was more enjoyable.

5.3.1.2 Results of Children's Observation

One of this study's objectives was to measure the level of efficiency, efficacy, and satisfaction of the 123GO game. The International Organization for Standardization (ISO) (1998), defines a usability test as the extent to which a product can be utilised by certain users to achieve specific goals with efficiency, satisfaction, and effectiveness, given a specific context. This definition has three important components:

1. **Effectiveness:** The completeness and accuracy of the manner by which customers achieve specified goals.
2. **Efficiency:** A goal's completeness and accuracy in relation to the resources.
3. **Satisfaction:** Being freed from discomfort and possessing positive attitudes towards system use.

Given the definition of usability, it is apparent that effectiveness and efficiency are two components that have objective characteristics. On the other hand, satisfaction is more subjective. Therefore, measurement of the metrics for effectiveness and efficiency can be done by using a usability measurement that was introduced by Nielsen (2001). Doing so involves measuring and analysing the user's success rate, which is the simplest usability metric. Based on the research conducted by Nielsen (2001), success rate can be defined as the percentage of tasks that users are able to correctly complete.

However, this metric cannot really say why users fail or how well their performance in their complete task was. It is easy to measure and collect success rates. A task is deemed a failure if users cannot do it. In this study, the researcher used an observation checklist while performing the usability test in order to measure the user success. Satisfaction was measured using the post questionnaire given to the children.

1. **The Results of Effectiveness:** The ability of the user to complete a task in the application is measured by effectiveness (Rubin, & Chisnell, 2008). In this study, effectiveness was measured at each interface, and each interface represented the game levels. There was a list of all the tasks that had to be completed. A task that was successfully completed was marked with a 'Yes'. A full credit of 100% was given to every success mark. A 'No' mark was given to tasks that were not successfully completed. 'No' marks have zero 0% credit.

A task is deemed unsuccessful if, for example, the child gives up, is unable to complete the task time, or if the child completes the task incorrectly, among others. The 'Partial' mark signifies a partial credit and will give the user a 50% credit. Giving partial credit is up to the researcher's discretion. The list of tasks evaluated for effectiveness can be seen below. For easier analysis, the collected data were summarised and analysed for its effectiveness using the success rate evaluation:

Table 5.1: List of Tasks for The Effectiveness Evaluation

Screen / Evaluation Element	Child 1	Child 2	Child 3	Child 4	Child 5
The child show positive reaction during the game play.	Yes	Partial	Yes	Yes	Yes
The child do not find trouble to complete the game	Yes	Yes	Yes	Yes	Yes
The child give focus to the game	Yes	Yes	Yes	Yes	Partial
The child succeeded in completing each level of the game from first try	Yes	Partial	Yes	Yes	Yes
The child do not find trouble to navigate between pages	Yes	Yes	Partial	Yes	Yes
The child can easily learn the same mistakes and not repeating it.	Yes	Yes	Yes	Yes	Yes
The game was fun	Yes	Yes	Yes	Yes	Yes
The game was easy to play	Yes	Yes	Yes	Yes	Yes
The children love the game	Yes	Yes	Yes	Yes	Yes
I want to play this game again	Yes	Yes	Yes	Yes	Yes
I would like to play this game at home	Yes	Yes	Yes	Yes	Yes
The child succeed in choosing the correct answer	Yes	No	Partial	Yes	Yes

Levels of the game are suitable for the child	Yes	Yes	Yes	Yes	Yes
The child knows whether their answer is correct or no	Partial	Yes	Yes	Yes	Yes
Graphics used on the page attract the child	Yes	Yes	Yes	Partial	Yes
Size of the game window opened is good enough	Yes	Yes	Yes	Yes	Yes
The child knows what to do during the game play	Yes	Yes	Yes	No	Yes
The Child can match the answers correctly	Yes	Partial	Yes	Yes	Yes
The child selected the correct menu to start the levels of game	Yes	Yes	Yes	Yes	Yes
The child can easily recover from errors or mistakes that happened	Yes	Yes	Yes	` Yes	Yes
Audio is use fil to help the child learn	Yes	Yes	Yes	Yes	Yes
Guide and help from researcher was minimal	Yes	No	Yes	Yes	Yes

The summarized data is shown in Table 5.2.

Table 5.2: Summary of Effectiveness Analysis Table

Answer	Child 1	Child 2	Child 3	Child 4	Child 5	Subtotal
Yes	21	17	20	20	21	99
Partial	1	3	2	1	1	8
No	0	2	0	1	0	3
TOTAL						110

In Table 5.1, 5.2 tasks are shown and each task has 5 attempts, giving a total of 110 task attempts. Out of this number, there were 99 successful attempts and 8 partially successful ones. There are total of 3 unsuccessful tasks will be ignored and placed as part of 3 × 0% = 0. The equation (Ismail, Diah, Ahmad, Kamal, & Dahari,2011) shown below was used to compute the overall effectiveness rating for this set of tasks:

$$\text{Effectiveness (\%)} = (\text{Yes} + (\text{Partial} \times 0.5)) / \text{Total} \times 100\%$$

$$= (99 + (8 \times 0.5)) /110 \times 100\%$$

$$= 93.64\%$$

Using the equation above, the usability testing for the children revealed that the 123GO 's effectiveness is 93.64%. The effectiveness result of 93.64% proved that the prototype is completeness and usable for achieving specified number sense children goals.

2. **The Results of Efficiency**: The smoothness of task completion is measured by the efficiency. The method and algorithm used in measuring efficiency is the same as the one used for measuring effectiveness. A smoothly completed task is marked with a 'Yes'. Again, a success mark has a full 100% credit. A 'No' mark is given for tasks that are not completed smoothly. Zero 0% credits are awarded to 'No' marks. Examples of unsuccessful tasks can include the child not being able to complete the task at the first attempt or the child needing assistance from the researcher (Ismail, Diah, Ahmad, Kamal, & Dahari, 2011; Diah, Ismail, Ahmad, & Dahari, 2010).

Table 5.3: Analysis of The Efficiency Using Success Rate Evaluation

Screen / Evaluation Element	Child 1	Child 2	Child 3	Child 4	Child 5
The child selected the correct menu to start the levels of game	Yes	Yes	Yes	Yes	Yes
The child can easily recover from errors or mistakes that happened	Yes	Yes	Partial	Yes	Yes
The child do not find trouble to navigate between pages	Yes	Yes	Yes	Yes	Yes
The child do not have trouble to find the start menu	Yes	Partial	No	Yes	Yes
Error and mistake done by the child was minimal	Yes	Yes	Yes	Yes	Yes
The child knows how to recover from errors and mistakes	Partial	Yes	Yes	Yes	Yes
The child succeed in choosing the correct answer	Yes	Yes	Yes	Yes	Yes
Level of interaction between researcher and the child was minimal	Yes	Yes	Yes	Yes	Yes
Guide and help from researcher was minimal	Yes	Yes	Yes	Yes	No
The child completed the game in the first try	Yes	Yes	No	Yes	Yes
The child knows whether their answer is correct or No	Yes	Yes	Partial	Yes	Yes
The child knows what to do during the game play	Yes	Yes	Yes	Yes	Yes

From Table 5.4, we can summarize all results into a simpler efficiency analysis table as in Table 5.3 below.

Table 5.4: Summary of Efficiency Analysis Table

Answer	Child 1	Child 2	Child 3	Child 4	Child 5	Subtotal
Yes	11	11	8	12	11	53
Partial	1	1	2	0	0	4
No	0	0	2	0	1	3
TOTAL						60

It can be seen on from table 5.4 that there are 2 tasks and each task has 5 attempts, for a total of 60 task attempts. Of the 60 attempts, 53 were successful and there were 4 partially successful tasks. Three unsuccessful tasks were ignored and signified by $3 \times 0\% = 0$. The equation (Ismail, Diah, Ahmad, Kamal, & Dahari,2011) below was used to determine the overall efficiency rating for this set of tasks:

$$\text{Efficiency (\%)} = (\text{Yes} + (\text{Partial} \times 0.5)) / \text{Total} \times 100\%$$

$$= (53 + (4 \times 0.5)) / 60 \times 100\%$$

$$= 91.6\%$$

Using the above equation, the usability testing with children has led to the computation of a 91.6% efficiency rating for the 123GO educational game. The efficiency result of 91.6% proved that the prototype accuracy in relation to the resources of the guidelines for achieving specified number sense children goals.

3. **The Results of Satisfaction:** By using the questionnaires, the children's satisfaction ratings were measured. In other words, children are needed to answer these questions after completing all test scenarios. The 5 point Likert scale was used to add structure to the questions and answers (Ismail, Diah, Ahmad, Kamal, and Dahari, 2011). Table 5.5 below shows the point Likert scale ranged from 1 to 5.

Table 5.5: Likert Scale Points Table Used in Questionnaire

Answer Options	**Likert Scale**
Yes, very much	5 points
Yes	4 points
Moderate	3 points
Not really	2 points
Not at all	1 points

The questions were adopted from Ismail, Diah, Ahmad, Kamal, and Dahari, (2011) were designed in order to determine how the children felt about the game, how they liked it, and how easy it was for them. Table 5.6 shows the questionnaire and the children's answers, all presented in Likert scale points.

Table 5.6: Likert Scale Points Table Used in Questionnaire with Children

Test Questionnaire	Child 1	Child 2	Child 3	Child 4	Child 5	Subtotal
The game was Fun	5	5	5	5	4	24
The game was easy to play	4	5	4	5	5	23
I like the game	5	5	4	4	4	22
I do not find trouble to navigate between pages	4	5	5	5	4	23
The selection of easy answers	5	4	5	5	5	24
I want to play this game again	5	5	5	5	5	25
I would like to play this game at home	5	5	5	5	5	25
TOTAL						166

The 5 point Likert scale had a negative weighting represented by 1 and a positive weighting represented by 5. Each question answered by the 5 children had a possible positive response factor of 8 points. Since there were 7 questions, a total of 175 points represented 100% satisfaction. The net equation was used to calculate the satisfaction rating for the overall game:

$$\text{Satisfaction (\%)} = \text{Answer Point} / \text{Total Point} \times 100\%$$

$$= 166 / 175 \times 100\%$$

$$= 94.86\%$$

Using the above equation, the usability testing with the children revealed that the satisfaction rating for the 123GO educational game was at approximately 94.86%. The satisfaction result of 94.86% proved that the children like the prototype and very satisfy with it.

4. The Results of Single Metric for Usability:

Measurement of the application's overall usability (effectiveness, efficiency and satisfaction) involved expressing each usability component as a percentage. These three scores were averaged in order to compute the usability of a product. The overall usability can have a value ranging from 1–100. The effectiveness evaluation summary is presented by Table 5.6. Table 5.7 shows the calculation for the effectiveness rating. Based on the calculations, the rating was found out to be 93.64%. This value is a proof that the 123GO app was used effectively by the challenging children. Table 5.9 shows the summary of the efficiency measurement.

The overall rating was 90% and this proves that the 123GO was used efficiently by the challenging children. The calculation for the satisfaction rating is presented on Table 5.11. of the app garnered a score of 94.86%. This value reveals that children were satisfied with their use of the 123GO. The usability rating was calculated by calculating the average of the three measurement scores:

$$\text{Usability (\%)} = (\text{Effectiveness} + \text{Efficiency} + \text{Satisfaction})/3 \times 100\%$$

$$= (93.64 + 91.6 + 94.85) / 3 \times 100\%$$

$$= 93.36$$

Using the above equation, it can be seen that the usability testing with children has revealed that the 123GO educational game has a usability level of approximately 93.36%. At the end, using the usability test results in 93.36%. Wherein, 93.64% by considering the effectiveness value of 123GO, 91.6% by considering the efficiency of 123GO and 94.83% by considering the satisfaction of 123GO.

5.4 Summary

This chapter defines and reviews the app from the user's viewpoint. The factors associated with the performance as well as the practicability checks were thoroughly described – related to the processes and outcomes. The processes are distinct and the outcomes are consistent. The outcome of 93.36% verified that the tool is employable for stimulating youngsters. The practicability ranking is measured using the average value of effectiveness, efficacy, and satisfaction. Considering the effectiveness value of 123GO is 93.64%, it demonstrates that 123GO is a simple tool that could help children accomplish their objective.

Similarly, the efficiency value of 91.6% indicates that the tool can be used effortlessly in carrying out the assignments. Furthermore, the satisfaction value of 94.86% illustrates that children approve the tool and are quite pleased with it. Therefore, the users professed that the app was beneficial and convenient, considering the outcomes displayed in this chapter. The next chapter will review the inference drawn from this evaluation and suggestions for further investigation.

CHAPTER SIX
CONCLUSION

6.1 Introduction

This chapter gives a review of the 123GO model formation evaluation and its outcome. As the evaluation's goals were clearly defined in Chapter One, in Chapter Two, the current apps were particularised. These prevailing apps were used as a base for choosing the components to recommend design principles with regards to IXD, to make 123GO employable based on the users' view. This evaluation's complete method starting with problem identification right up to the study of the outcome is systematically explained in Chapter Three. Chapter Four comprises an explanation of the conception of 123GO, the model of an Edutainment app intended for number sense kids who have low numerical competence problems. The outcomes and investigation are then reviewed in Chapter Five.

6.2 The Achieved Objectives

On completion of the tasks defined in Chapter Three, which were then explicated in Chapter Four, this evaluation has achieved all the specified goals that were defined in Chapter One. These goals are also explained as follows:

1. **Objective One:** To construct educational game design guideline based on IxD dimensions of form, content and behavior.

With a view to obtain an understanding to design principles pertinent to the informative game app that alerts kids to fluidity and flexibility with numbers, this evaluation is reliant on former and current apps that are there for those suffering from dyscalculia and number sense, which are specified in Chapter two. With the help of these apps, the components to design principles appropriate to the informative app being evaluated can be determined, which were recommended considering IXD.

2. **Objective Two:** To design and develop educational game prototype incorporating the guideline constructed in (1).

The 123GO app's structure has been defined based on resultant design fundamentals and requisites that were collected in Chapter five. 123GO is an interactive system that helps children to develop their mathematical abilities; this is achieved through the demonstration of number sense learning and mathematical skills as progressive assignments to derive the correct solutions. Once the design has been confirmed, an operational model interpretation was formed and thoroughly explained in Chapter four. Every design principle which was collected depending on IXD, as described in Chapter three, is combined in this model.

3. **Objective Three:** To evaluate the effectiveness of the proposed design of educational game using usability testing measuring effectiveness, efficiency and satisfaction.

The launch of the 123GO app has taken place; it has also been checked for its professed practicality and convenience. Chapter five gives the specifics of the evaluation, where the outcome achieved proves that the users have good reviews of the app with regards to both its practicality and convenience. The model features were first observed to guarantee that they function properly as proposed.

6.3 Limitations and Recommendations for Future Studies

Even though it has been effective in numerous ways, the execution and the assessment of the 123GO setting has emphasised some serious concerns. Hereafter, we take a quick look at the major restrictions faced in forming the 123GO app as we consider that they are not explicitly related to 123GO but, more commonly, to the layout and assessment of apps for number sense. One of the main restrictions is the minimal writings existing for analysis regarding the considered field. This prototype emphasises on advancing just three types of mathematical skills: coaching the child to read and write the numbers, coaching the kid about sequential order and relationship between the numbers as well as coaching the kid on addition, subtraction, multiplication, and division.

The points that are not worked on in this prototype are assessing the numbers and geometric figures. With respect to further efforts, the evaluation has brought up a number of concepts and propositions for further efforts that can be accomplished in future research. Thus, for future development work a prototype will be considering the points which are not employed in the current prototype. The opinions and views of the users are the motivating power for further upgrades. Five improvements under contemplation are:

1. The investigators should include more sample information of a larger number of examples to derive a better outcome. For this evaluation, the examples were obtained from Sekolah Kebangsaan Mergong, Alor Setar, Kedah, Malaysia, and opinions of the teachers were the only feedback. For

further research, the investigators should also consider examples from various places like rural regions and they could get the requisites from the tool as well as the teachers. Additionally, the investigators could improve the application software model by using other settings.

2. The range of this evaluation is restricted to children. Therefore, more improvements have to be brought about to include individuals from different age groups with number sense problem.
3. This evaluation emphasised only on Malay and English languages but we can use it on any foreign language in a similar way.
4. If additional mathematical skills are integrated in the app, it would make the app even more exciting.
5. Permit guardians to distribute the material by using Wi-Fi to connect their mobiles.

6.4 Contribution of Research

The aim of this study is to contribute to the teaching and learning number sense using technology to help children with Dyscalculia and low numeracy through the design and implementation of useful and easy-to-use educational game. Best design principle means designing systems, in essence, that stimulate fun to use, and the application of those principles suitable for children game with number sense learning.

The importance of the study takes not only the children with Dyscalculia and low numeracy into account, but also the implementation of the pedagogy approach, which can be summarized shortly:

1. Participants who use technology devices are more interested in learning as these technologies combine playing with learning.

2. Teachers who depend on technology devices are more interest in learning, as these technologies more ease and flexibility being enhanced with Audio and Visual effects.

6.5 Summary

This evaluation asserts positively that its influences are substantial on comparing the accomplishment of goals. It gathers inputs from different points to create a substantial influence on the amount of data using the recommended model. For further work, other investigators could employ the recommended model for further development. Apart from this, the evaluation aids the general public as the created model offers a unique facility to teachers and parents, helping them provide the education and attention required by their children.

Eventually, this invention will lead to children with number sense achieving better performances. These kids will mature, leading more content and fruitful lives, resulting in the entire world profiting from their offerings. Lastly, this evaluation has realised the defined goals. As discussed in the earlier unit, some imminent thoughts should be considered to improve enterprise.

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Appendix

Appendix A

UNIVERSITI UTARA MALAYSIA

College Of Arts and Science

School of Computing

The purpose of this interview is to ask questions educators and instructors to collect data related to the use of technology to help the dyscalculia children, the questions are:

student

Hazim Majeed 3/11/2015

FARIZA MOHAMAD AKHIR
3/11/2015

HASHIMAH MARZEKI
3/11/2015

NOORIZANI TOHARI
3/11/2015

SEKOLAH KEBANGSAAN MERGONG
ALOR SETAR
KEDAH

Appendix

Appendix B

Functionality Test 1: Children select language Functionality

<table>
<tr><td>Functionality Test: select language of the 123GO</td><td>Priority (H,L): High</td></tr>
<tr><td colspan="2">Test Objective: The Page appear in selected language</td></tr>
<tr><td colspan="2">Test Description: Explains the choice of language by the user</td></tr>
<tr><td colspan="2">Requirements verified: Yes</td></tr>
<tr><td colspan="2">Test environment: Samsung Galaxy Grand Gt-19082, Android version 4.2.2 and Eclipse IDE</td></tr>
<tr><td colspan="2">Test step/Pre Condition:
1. Child chooses the language
2. The child moves to the levels page</td></tr>
<tr><td>Actions: the child choose the language and navigation to the home page</td><td>Expected Results: The app displays the page of in the language selected.</td></tr>
<tr><td>Pass: Yes</td><td>Fail: No</td></tr>
<tr><td colspan="2">Problem: Nil</td></tr>
<tr><td colspan="2">Notes: Successfully Executed</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Functionality Test 2: Level selection

<table>
<tr><td>Functionality Test 2: Child level select</td><td>Priority (H,L): High</td></tr>
<tr><td colspan="2">Test objective: The objective of the application learn the children mathematical skill</td></tr>
<tr><td colspan="2">Test Description: the application consists of three levels, first Clarify the meaning of number, second, spatial value to the number and third exercises</td></tr>
<tr><td colspan="2">Requirements verified: Yes</td></tr>
<tr><td colspan="2">Test environment: Samsung Galaxy Grand Gt-19082, Android version 4.2.2 and Eclipse IDE</td></tr>
<tr><td colspan="2">Test step/Pre Condition:
1. The app displays the level's list to the child.
2. The child selected the level's game.
3. The child can return to the language page by press is on the home button.</td></tr>
<tr><td>Actions: The child open the level page of app to interact with it</td><td>Expected Results: It was starting a new task to learn</td></tr>
<tr><td>Pass: Yes</td><td>Fail: No</td></tr>
<tr><td colspan="2">Problem: Nil</td></tr>
<tr><td colspan="2">Notes: Successfully Executed</td></tr>
</table>

Functionality Test 3: The Beginner Level

Functionality Test 3: Child Select Beginner Level	**Priority (H,L):** High
Test objective: The child begins to learn the numbers	
Test Description: In this phase the child learns the meaning of number in addition to how to pronunciation and number writing.	
Requirements verified: Yes	
Test environment: Samsung Galaxy Grand Gt-19082, Android version 4.2.2 and Eclipse IDE	
Test step/Pre Condition: 1. The app displays three options. 2. The first option teaches the child the meaning of numbers and how to pronounce them. 3. The second option teaches the child how to write the number. 4. The third option restores the child to home page	
Actions: Child learn the meaning of numbers, Pronunciation and writing the numbers	**Expected Results:** The app helped the child to learn numbers
Pass: Yes	**Fail:** No
Problem: Nil	
Notes: Successfully Executed	

Functionality Test 4: The Intermediate Level

<table>
<tr><td>Functionality Test 4: Child Select Intermediate Level</td><td>Priority (H,L): High</td></tr>
<tr><td colspan="2">Test objective: The child learns how arrange numbers in ascending order and descending order.</td></tr>
<tr><td colspan="2">Test Description: At this stage, the child learns the sequence of digits on the diagram of numbers.</td></tr>
<tr><td colspan="2">Requirements verified: Yes</td></tr>
<tr><td colspan="2">Test environment: Samsung Galaxy Grand Gt-19082, Android version 4.2.2 and Eclipse IDE.</td></tr>
<tr><td colspan="2">Test step/Pre Condition:
1. In first option, comparison between two numbers and determine the who is smallest.
2. In second option, comparison between two numbers and determine the who is biggest.
3. In third option, determines what is the previous number.
4. In fourth option, determines what is the next number.
5. In fifth option, back to the home page.</td></tr>
<tr><td>Actions: The child began to learn the ascending order and descending order of numbers.</td><td>Expected Results: The app display the icon of main categories on middle of page.</td></tr>
<tr><td>Pass: Yes</td><td>Fail: No</td></tr>
<tr><td colspan="2">Problem: Nil</td></tr>
<tr><td colspan="2">Notes: Successfully Executed</td></tr>
</table>

Functionality Test 5: The Advance Level

<table>
<tr><td>Functionality Test 5: Child Select Advance Level</td><td>Priority (H,L): High</td></tr>
<tr><td colspan="2">Test objective: Learn child the mathematical calculations</td></tr>
<tr><td colspan="2">Test Description: At this stage, the child learns addition, subtraction, multiplication and division</td></tr>
<tr><td colspan="2">Requirements verified: Yes</td></tr>
<tr><td colspan="2">Test environment: Samsung Galaxy Grand Gt-19082, Android version 4.2.2 and Eclipse IDE</td></tr>
<tr><td colspan="2">Test step/Pre Condition:
1. In first option, the assignment to collect between two numbers and three answers was presented by the app, the duty of the child to choose the correct answer.
2. In second option, the assignment to subtract between two numbers and three answers was given by the app, the duty of the child to choose the correct answer.
3. In third option, the assignment to multiplication between two numbers and three answers was given by the app, the duty of the child to choose the correct answer.
4. In fourth option, the assignment to division process between two numbers and three answers was given by the app, the duty of the child to choose the correct answer.
5. In fifth option, back to the home page</td></tr>
<tr><td>Actions: the child learn the mathematical operations the easy way</td><td>Expected Results: The app display the forms of images mathematical operations in middle of page</td></tr>
<tr><td>Pass: Yes</td><td>Fail: No</td></tr>
<tr><td colspan="2">Problem: Nil</td></tr>
<tr><td colspan="2">Notes: Successfully Executed</td></tr>
</table>