Design and Development of Lost Boy Calculic Adventure: A Mobile Game-Based Learning for Year 1 Dyscalculic Children

Subashini Annamalai(✉) and Nur Fadziana Mohamed Faisal

School of Multimedia Technology and Communication, Universiti Utara Malaysia, Kedah, Malaysia
subashini@uum.edu.my

Abstract. Dyscalculia is a specific sort of learning impairment that affects mathematic processes such as counting numbers, recalling phone numbers, and understanding speed, time, and distance. In order to help the learning of dyscalculic children, a mobile game-based learning application named Lost Boy Calculic Adventure (LBCA) was designed and developed for the use of Year 1 dyscalculic children. This application was meant to be an early intervention to encourage these children to learn and practice Mathematics in a motivating and fun way. The design and development of this assistive mobile game-based learning application which is based on the ADDIE (Analysis, Design, Develop, Implement, and Evaluate) Model are described in this paper. This paper also includes details on the user acceptance evaluation of the prototype. The findings of the evaluation indicated that the respondents are satisfied with the design of the prototype and it can help to improve their numerical skills as an early stage of recovery intervention. This research will contribute to the betterment of the education quality of individuals with learning difficulties and it is an attempt to support the children with learning disabilities such as dyscalculia to be able to learn effectively like normal children.

Keywords: LBCA · Dyscalculia · Year 1 · Primary · game-based learning · mobile application

1 Introduction

Dyscalculia, a specific learning difficulty linked to executing mathematical operations is a specific learning disability [1], ranges from 3% to 7% in people who are school-aged [2]. This mathematical impairment makes it extremely difficult for kids to perform simple calculations like counting, memorising phone numbers, and comprehending time, distance etc., which also has an impact on their usual academic activities [3].

Dyscalculia is a disorder in which a person lacks the necessary numerical skills [4], however most children with dyscalculia appear to excel in other areas of learning [4]. Children with dyscalculia often experience high levels of mathematics anxiety, which leads to a lifelong problem [5]. Nevertheless, this can be eased with well-targeted support and intervention [3, 4].

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Children with dyscalculia can benefit from using technology in the classroom since it makes it easier to give resources quickly and fosters collaborative learning. The use of technology also increases the effectiveness and interaction of learning. It may be used to accelerate, improve, and increase fundamental math abilities [4]. According to research, the most effective treatment for dyscalculia is for parents and teachers to engage children in appropriate mathematics interventions, such as playing math games, using multimedia tools that highlights the use of visual techniques, such as drawing a figure or diagram, and encouraging them to keep practicing problems repeatedly without getting bored [6]. This is due to the fact that simultaneous auditory and visual information boosts memory capacity in pupils, according to the cognitive learning hypothesis of multimedia learning [6].

Morin [7] found that educational games and entertaining learning resources help dyscalculic youngsters learn more effectively. This approach is a useful way for them to practise their arithmetic abilities and might help them feel less anxious about math in the process. They might be taught informally by playing the math games [8]. A research by Ariffin [8] indicated that the dyscalculic children who used mobile applications to study arithmetic exhibited substantial improvements. As a result, it is recommended that students play educational games as an additional exercise to strengthen their arithmetic abilities rather than complete math exercise books [6, 8, 9].

2 Issues With Mathematics Learning Among Dyscalculic Children

In the current setting, traditional method is being used by most schools in Malaysia [8]. There are very few dyscalculic children's educational mobile apps and games being researched or created in Malaysia [9, 10]. The existing game-based learning applications for Mathematics learning that have been developed for young learners with dyscalculia are not compatible with Malaysian primary school syllabus. Perelmutter, McGregor, and Gordon [11] suggested that a one-size-fits-all mobile application would not be the best way to help individuals with learning disabilities to learn more effectively. It might satisfy a portion of people in one environment context but not all. Instead of a universal mobile application, a customized learning mobile application is required [12].

It is claimed that the mobile app designers and developers are lacking guidance on how to design appropriate mobile app for children with learning disability [13]. The designer and developers are encouraged to follow a correct design principle as a rule of thumb to create work which will never frustrates the users especially in catering to users who have specific disability with dyscalculic constrains. This is due to the fact that this community's interaction, participation, and informational interpretation are crucial to the understanding and usage of such applications.

2.1 Proposed Solution

Universal Design for Learning (UDL) principles offer one way to meet the requirements of various learners [14]. UDL actively applies instructional design principles, pedagogical expertise, and instructional technology to develop education that is engaging and accessible to students of all abilities, [15]. UDL promotes learning experience design

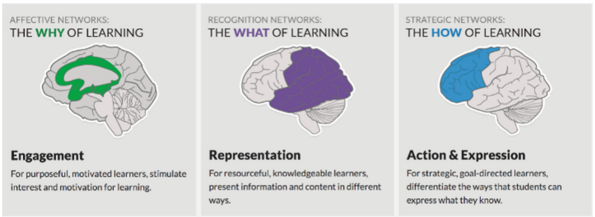

Fig. 1. Three principles of Universal Design for Learning (UDL).

that will assist all students in achieving their academic objectives since it welcomes diversity and variety as the norm of any learning environment. Figure 1 depicts the three dimensions of learning—engagement, representation, and action and expression—that are accessed through various ways for the benefit of all learners.

UDL principles provides a foundation for designing the content aspects of the course, including the presented materials (representation), the opportunities offered to the students (action and expression), and the learning environment fostered to encourage motivation (engagement). This framework allows the educator to think about how the instruction and lesson should be designed with flexibility to meet the needs of learners with Dyscalculia. In developing ideas for lessons to be included in the mobile game-based learning (MGbL) application, the following questions under each UDL principle will be considered:

i. Representation: What is the suitable way to present information and content to Dyscalculic students?
ii. Engagement: How could instructions be framed to promote motivation?
iii. Action& Expression: What type of interactivity is suitable for Dyscalculic students?

Guided by UDL principles, the researchers attempted to design and develop a mobile game-based learning (MGbL) that will help in improving the numerical skills of dyscalculic children in Malaysia, particularly Year 1 students as early intervention tool. This paper will describe the process of design and development of a mobile game-based learning application named Lost Boy Calculic Adventure (LBCA) and reports the user satisfaction evaluation of the developed mobile application as an educational tool that will help in improving the numerical skills of these children.

3 Design and Development of Lost Boy Calculic Adventure (LBCA)

Lost Boy Calculic Adventure or in short LBCA is a mobile game based learning application that was designed and developed based on the ADDIE (Analysis, Design, Develop, Implement and Evaluate) Model.

Mathematical assistive multimedia tools designed for dyscalculia and information about dyscalculia itself were researched in the literature review during the first step, which is known as the analysis phase. Additionally, information on the issues faced by children with dyscalculia was investigated and examined. Following the collection of the data, a content review study of the current mobile apps for dyscalculia was carried

out, which allowed for the accurate identification of the design elements for the LBCA application for dyscalculic children.

In the design phase, the details gathered in phase 1 was integrated into the design of the mobile game based learning application. Documents that were essential to aid the development of the application, such as Mathematics Year 1 Special Education syllabus, storyboarding sheets and production files was designed and created. Upon completion of the design documents, the development process in the third phase begins.

The third phase, known as the development phase, enables the development and assembly of the necessary components to create a prototype for the mobile game-based application. Various software were used in the development of this mobile application, namely Unity Real-time Development Platform for the development, Adobe Audacity for audio editing, Adobe Photoshop and Adobe Illustrator for graphic editing, and Wondershare Filmora for video editing. The characters and the graphics were drawn individually prior to the development of the prototype. Some of the graphics, background music and sound materials were taken from the royalty free downloadable websites. The content of the application was created based on the Malaysian Special Education Syllabus for Year 1 Mathematics while interface and interactivity was developed based on the UDL principles. Once the development process was done, the prototype was pilot tested which involve two evaluations: alpha test and beta test. Experts in user interface, language, and content reviewed the application during the alpha test. This verifies that the prototype functioned as intended. Following the alpha test, the prototype underwent modification and a beta test that assessed the usability (usefulness, ease of learning, and satisfaction) components before being made accessible to potential users.

The prototype has to be deployed in a real setting during the implementation phase. For this purpose, a primary school that has special education classroom that acts as an educational hub for dyscalculia children were chosen. The prototype was then employed to the children assisted by their teacher after instruction on how to use the prototype were given.

In the final phase which is evaluation phase, the developers evaluated the user acceptance elements of the developed LBCA prototype as an early intervention to assist the dyscalculic children with their Mathematical skills. The mobile application that has been developed in the earlier phase was evaluated using a questionnaire that was adapted from the Lund (2001) USE questionnaire and revised accordingly to suit the Year 1 children. The findings of this phase provide recommendations to promote improvement on the prototype.

Figure 2 illustrates the design and development process of 'Let's Talk Now' mobile app.

3.1 Content of LBCA

Lost Boy Calculic Adventure (LBCA) is a Mathematics based mobile game-based learning application which focuses on Year 1 students in Malaysia that has dyscalculia. The purpose of this application is to help the Year 1 dyscalculic children to identify math numbers, symbols, time and improve their Mathematics arithmetic skills. It can be a instructional tool to motivate the students to learn mathematics in a fun and enjoyable way.

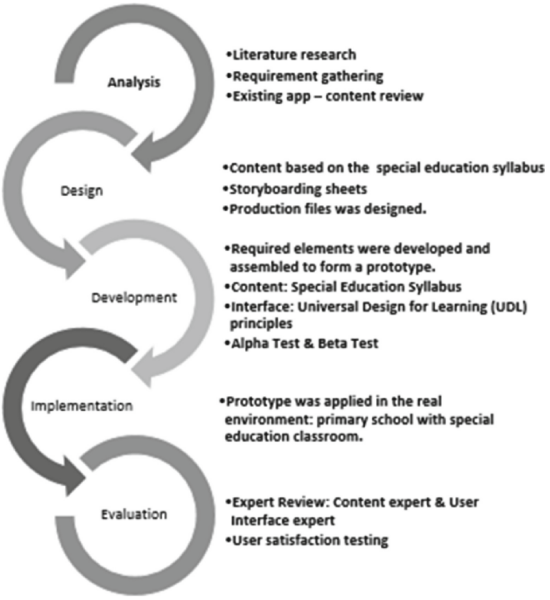

Fig. 2. The design and development process of Lost Boy Calculic Adventure mobile game-based learning application

LBCA application consisted of 16 levels, each level represented each chapter that based on the Year 1 Mathematics Special Education syllabus. Every level has different theme. So, the children will experience different theme of gameplay when they unlock each level.

The application starts with main menu. When the user/player clicks the play button, the storyline will be shown first to tell a story. The returning player will be given an option to skip the storyline. Then the player will enter the game level interface and he/she are allowed to select the level they prefer if they have successfully unlocked the levels. However, the user cannot proceed to next level if they cannot unlock the current level. According to this method, users are being forced to challenge themselves to complete each level in order to move to next level. Each level represents one topic and is attached with its learning tutorial video before the user starts to play.

The game controller consisted of three button which are "left", "right" and "up" arrow button that can used to control the movement of main character. The main character will meet obstacles in the form of topical Mathematical questions and must answer them correctly in order to finish the level. If incorrect, they are given another chance to answer the same question. Finally, the scoreboard will be shown and the main character will be rewarded.

Figures 3, 4, 5 and 6 illustrate some of the main interfaces of Lost Boy Calculic Adventure (LBCA) mobile game.

Fig. 3. Game level

Fig. 4. Topical tutorial video

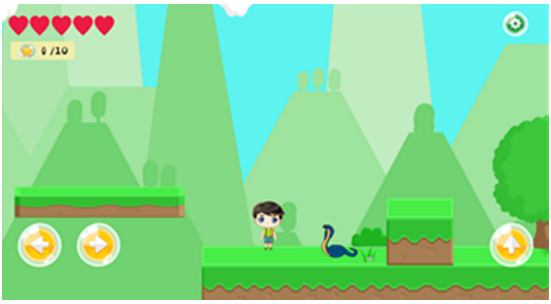

Fig. 5. Game interface

4 User Acceptance Evaluation of LBCA

A user acceptance evaluation was conducted to potential users who are dyscalculic children, assisted by their teacher. The evaluation only investigated the user acceptance of the BLCA mobile game-based learning application from the perspective of 15 respondents who are dyscalculic children.

Prior to the evaluation, the respondents were given a brief instruction on how to use the prototype. For the purpose of the evaluation, a revised questionnaire that was adapted

Fig. 6. Topical question

from Lund [16] USE questionnaire with the Likert scale of 1 (Strongly Disagree) to 5 (Strongly Agree) was employed as an instrument. The instrument contains 13 items on usefulness (USE), ease of learning (EOL), and satisfaction (S). Data collected were then analyzed to ensure that the respondents' acceptance of the LBCA prototype and were no errors and the prototype manage to deliver its intended purpose. Table 1 represents the demographical findings of the user acceptance evaluation.

Descriptive statistical analysis was used to analyze the data obtained in the evaluation process. Table 2 describes the summary of findings from the questionnaire.

The first construct is the usefulness aspect. The high mean scores which is closer to 5.00 indicated that the mobile app is useful in meeting the dyscalculic children's need and are able to help the children to learn Mathematical skills in a fun way. As for the ease of learning construct, the mean score of 4.60 for the items suggests that the dyscalculic children are able to easily remembers how to use the mobile app and learn to use the mobile app quickly. For the satisfaction construct, mean scores are also 4.67 which is

Table 1. Demographical findings

Section	Details	Item	Findings
Demographic	Gender	Male	8 (53.3%)
		Female	7 (46.7%)

Table 2. Questionnaire findings

Construct	Neutral	Agree	Strongly Agree	Mean
Usefulness (USE)		3 (20%)	12 (80%)	4.80
Ease of Learning (EOL)	2 (13.3%)	2 (13.3%)	11 (73.3%)	4.60
Satisfaction (S)		5 (33.3%)	10 (66.7%)	4.67

closer to 5.00 indicating that the respondents feel that they need to have the mobile app and that they are satisfied with the outcome of the mobile app. The mobile app functions as intended, according to the respondents' input. All the mean scores which are more than 4.50 ($4.50 < x < 5.00$) suggested that all the respondents who are dyscalculic children strongly agreed that the prototype of LBCA satisfy all the user acceptance construct as it is helpful, simple to understand, and the design and function of the mobile application is stated to be user friendly and satisfying.

5 Conclusion

Lost Boy Calculic Adventure (LBCA) is a mobile game-based learning application that was designed and developed specially for Year 1 dyscalculic children who are studying in primary schools in Malaysia. The objectives of this application is as early intervention tool to help them in improving their Mathematical skills. These children struggle with simple math tasks like counting, recalling phone numbers, and comprehending concepts like time, distance, and money counting. It is suggested that instead of doing Mathematic exercises book, student should play educational game as an extra exercise to improve their arithmetic skills. Therefore, this application will help them to help them in the process of learning. It is also to make their Mathematics lessons more engaging and motivating. This mobile game-based learning application is also expected to be an alternative learning tool in the classroom or outside the classroom revision. In addition, this application is also expected to be aid the teachers and parents of the dyscalculic children in the process of teaching the students in a normal learning environment.

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