A Gamified Learning Tool for Sri Lankan Primary Schools

R.A.G.K. Ranathunga, L.A.V.N. Rajakaruna, S.A.T.N. Karunarathne, L.N.Y. Abeywardena, D.P. Nawinna, T. Halloluwa

Abstract — **One of the critical problems in primary education sector particularly in Sri Lanka is inadequate resources for children who has special needs and Attention Deficit-Hyperactivity Disorder (ADHD) is a commonly observed among primary level children with symptoms like inabilities to pay attention and to stay on task. Such children are less interested in mathematics and have problems in learning the subject. To overcome above difficulties, the need for easy to use and effective learning aids has become vital and this research investigates on a possible way to support them using gamified learning infrastructure. 'Gamified Learning Environment for the Children with Special Needs in Primary Schools' is a learning tool that improves children's attitude towards mathematics in an interactive manner and the performance of children with learning difficulties. It comes with a gamified architecture with an interactive background, attractive graphics, colours, images and sounds. This system is designed as a web based learning environment that facilitates effective learning of mathematical concepts and badges, medals and rewards are distributed considering their achievements as a motivation technique. The intention of this automated tool is to deliver a user friendly automated learning tool grounded with proven effective pedagogy for affordable cost.**

Keywords— **Gamified Learning, Attention Deficit Hyperactivity Disorder, Primary Education, Learning Technologies, Graphical User Interface**

I. INTRODUCTION

Primary education is the most significant period of the education system for children and as well as for the parents in Sri Lanka. As a result of the competitive nature of education, the parents' expect to find a better school which assists their primary level children in further education up to the Advanced Level. Among those, there are a large number of primary children who are suffering from inability to pay attention and to stay on task. Attitude towards mathematics is described as a not much interesting subject among the children and this is a major difficulty faced by the children mentioned above.

Researchers have found out that attention is a critical factor in mathematics performance and achievement. Children with Attention Deficit hyperactivity Disorder (ADHD) scan detailed information in a little time, which contributes to careless errors in aligning numbers, attending to calculation signs, carrying numbers in addition, and cancelling numbers in subtraction.

R.A.G.K.Ranathunga is with the Sri Lanka Institute of Information Technology, Sri Lanka; e-mail: gayanikowsh@gmail.com.

L.A.V.N.Rajakaruna is with the Sri Lanka Institute of Information Technology, Sri Lanka, e-mail: vindyanadishani@gmail.com,

S.A.T.N.Karunarathne is with the Sri Lanka Institute of Information Technology, Sri Lanka, e-mail: knayandara@yahoo.com

L.N.Y.Abeywardena is with the Sri Lanka Institute of Information Technology, Sri Lanka: e-mail: nishaniyapa88@gmail.com

D.P.Nawinna is with the Faculty of Computing, Sri Lanka Institute of Information Technology, Sri Lanka: e-mail: dasuni.n@sliit.lk

T. Halloluwa is with the Faculty of Computing, Sri Lanka Institute of Information Technology, Sri Lanka: e-mail: thilina.h@sliit.lk

ADHD is associated with poor grades, poor reading and poor mathematics. Primary children in community samples who show symptoms of inattention, hyperactivity, and impulsivity also show poor academic and educational outcomes. Because it is difficult for children with ADHD to pay attention, it is also more difficult for them to hold information in minds in order to manipulate it [1]. The present study examines the effects of computer-assisted instructions on the mathematics performance and classroom behaviour of grade one to five primary school children with ADHD.

Therefore applying 'Gamification' concept is better for ADHD children who are with less attention to the mathematics. Gamification is the concept of applying game design thinking to non-game application to make them more fun and engaging. A core gamification strategy is rewards for players who accomplish desired task. Rewards, points, achievement badges or levels are some of encouraging techniques used in gamification. Making the rewards for an accomplishment of tasks visible to the players are ways of encouraging players to complete the task. Adding meaningful choice, increasing challenge and adding narrative are some other techniques used in this approach [2] [3]. 'Gamified Learning Environment for the Children with Special Needs in Primary Schools' is a learning tool that improves primary children's attitude towards mathematics. This improves performance of primary children with learning disabilities. It comes with an interactive background, attractive graphics, colours, images and sounds. This system is a web based learning environment that facilitates effective learning of mathematical concepts among primary children with learning difficulties. It is designed for the users with relatively less technical knowledge. The GUI's used are more colourful since the targeted user group would be children between ages 6-10. All GUI's will be easy for the children to use.

2. LITERATURE REVIEW

The concept of child development which emerged in the 20th century is now attracting more interest of researchers of education. Primary children with special needs must be given special attention in the field of child development. Lack of; Paying Attention and Stay on Task, Working Memory, Processing Speed, Long-Term Memory, Visual Processing, Auditory Processing and Logical Thinking and Reasoning are considered as the major characteristics of such primary children. According to National Institution of Mental Health [4] Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common childhood disorders that can continue through adolescence and adulthood.

ADHD is a neurobehavioral developmental disorder affecting about 3-5% of the world's population [5] [6]. Attention Deficit Hyperactivity Disorder is a condition that becomes apparent in some children in preschool and early school years. Sometimes it may persist into adulthood. About 60% of primary children diagnosed with ADHD retain this condition as adults. The principle characteristics of ADHD are inattention, hyperactivity, and impulsivity. [5] [6]

American Psychiatric Association proposed predominantly inattentive, predominantly hyperactive and impulsive, and combined types in the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) [7] .There are various symptoms under those three main characteristics. A child expressing inattention, failing to give close attention to details or making careless mistakes, does not seem to listen when spoken directly, has difficulty in organizing tasks and activities. In hyperactivity, fidgety, difficulty in staying seated or playing quietly, and running about or climbing excessively in inappropriate situations will appear commonly. Primary children with impulsivity often have interrupts or intrudes on others have difficulty in waiting for turn, blurts out answers before questions have been completed [8].

Dr. Ruwan M. Jayathunga M.D, SCCS Ontario, Canada has mentioned in The Island Online [5] that according to the US based statistics an estimated 3 to 5 percent of school age children suffer from ADHD. According to the research done for learning difficulties in primary children attending a special clinic at the Lady Ridgeway Hospital, it has been revealed that frequency of presentations with attention deficit hyperactivity is respectively Inattention, Hyperactivity & impulsivity [8]. It has been a major problem to the primary children's education. When characteristics like hyperactivity, distractibility, poor concentration, or impulsivity starts, it could affect the performance in school, social relationships, or ability to accomplish day-to-day activities badly. Therefore due treatment is required for such primary children. ADHD is typically treated with drug therapy (often stimulants such as Ritalin) or psychiatric counselling [9] [10]. National Institute

of Mental Health [NIMH] has declared although these behaviours are not in themselves a learning disability, almost one-third of all primary children with ADHD have learning disabilities Primary children with ADHD may also experience difficulty in reading, mathematics, and written communication [8] [11]. In a descriptive study of Attention Deficit Hyperactivity Disorder (ADHD) at Lady Ridgeway Hospital for Children, it has been mentioned that the age distribution of ADHD subjects' average age was 6.5 years (range: 4 -10 years) and also the sex distribution of ADHD subjects' Male: female ratio was 3.6:1 [12].

'Resource for School and Home' has mentioned some teaching techniques for parents and teachers. For parents: to focus on discrete rewards and consequences for appropriate and inappropriate behaviour (such as tangible rewards and treats, Movie night) and tangible reminders. For teachers: give directions to one assignment at a time instead of directions to multiple tasks all at once, vary the pace and type of activity to maximize the children's attention and Structure the children's environment to accommodate his or her special needs [13].A child psychologist as well as the father of a son with ADHD, Dr. Robert Myers, has mentioned five simple concentration building techniques for kids with ADHD [1]

Jackie Paxton and Teresa Shoemaker have found in their research that the provision of amusement that allow the child to focus on for extended amounts of time is important to increase a child's attention span. They have listed out examples of enjoyable activities that are useful in helping to increase the child's attention span. Further, they have mentioned that the most important aspect of these activities is to gain the child's interest first [14]. Susan Pitman, Senior Research Officer has indicated that the learning process of primary children is accelerated by video games involving information, academic content and problem-solving. It will also be useful for the primary children who are suffering from learning problems [15].

Joey J. Lee and Jessica Hammer, Teachers College, Columbia University have mentioned about Gamification in their research; [3] what is gamification; what are the goals or benefits of it and the three major areas in gamification namely Cognitive, Emotional, and Social that can be served as an intervention. There is Gamification of education in the school education process too. For example, children get points for completing assignments correctly. These points translate in to "badges" and more commonly, they are known as grades. Children are rewarded for desirable behaviours and punished for undesirable behaviours in such a rewarding system. If they perform well, children "level up" at the end of every academic year. But most children would not describe classroom-based activities in school as playful experiences. Because of that, game-like elements of school education system does not translate directly in to children's engagement [3].

Booker has stated that one of the advantages of playing games with peers is the quick feedback primary children receive. [16] It has been argued that differences in primary children's attitudes to mathematics are noticeable when playing games. Burnett considered that mathematical games capture primary children's enthusiasm and create environments favourable for learning. Research by Bright, G. W. Harvey, J. G., & Wheeler, M. M. [16] reported that games generate enthusiasm, excitement, total involvement and enjoyment. Ernest argued that children become motivated; they immerse themselves in the activity and they can enhance their attitude towards the subject over a period of time when playing games.

Griffiths and Clyne [16] observed when children are enjoying what they are doing, when they are motivated, when they have an interest in the outcome, it is more likely that learning will take place. Sullivan has declared that games may motivate primary children to learn. For primary children who do not enjoy mathematics, games allow teachers a method of building the children's interest [16].Primary children who have ADHD tend to be "concrete" thinkers. They often like to hold, touch, or take part in an experience in order to learn something new. It can be shown to the child that mathematics is meaningful and fun by using games and objects to demonstrate mathematical concepts [17].

Website "Duolingo" [18] offers language education free of charge for the world. It gives the opportunity to learn 6 languages namely French, German, English, Spanish, Portuguese, and Italian on an interactive interface. Another website referred and recommended by the researchers is, "Poraora" [21]. It is a free 3D virtual world designed to make the learning fun for primary children on literacy, math, geography and problem solving. "K-5 math" [20] is a website which provides the facility to help primary children with ADHD to gain skills and confidence in elementary school mathematics.

Foreign countries use gamified tools in their schools for the primary children with inability to pay attention. In Sri Lanka, gamification is not being used as a very active method of learning for the children with inability to pay attention. Introduction of an interactive, graphical & gaming interface for the primary children who are unable to pay attention, because of their lethargic attitudes towards studies and the less ability to grasp mathematics given in the exam oriented syllabus is the main objective of this research. The system has been developed according to the Sri Lankan domain and it is in Sinhala language. Methodologies to improve student performance as well as to encourage successful engagement of children using this application are studied in this research.

3. METHODOLOGY

3.1 Overview

The system is designed as a web application. Although the system mainly focused on children with special needs, it also can be used for the primary school children for better performance. The system can be introduced as a leisure time activity at primary schools under the instructions of the teachers. Its primary goal is to improve knowledge of mathematics in an interactive way for such primary children by involving them in a game to identify their weakness and improve them in the classroom. This system not only improves knowledge of mathematics but also the efficiency of the child in learning, as this game must be played within a specific time. This is an easy to use, attractive and interesting way for the parents as well as the teachers for keeping the primary children involving in studies in behaviour that is more active. The research area is narrowed down to mathematical concepts. The research mainly focuses on commonly identified disabilities such as inability to pay attention or having less attention. Primary children are always seeking to play a game or doing activities not related to studies. According to research papers, this is not because of their disability but because of their childhood mentality. Although ADHD itself is not a learning disability, researchers believe kids with ADHD may be more likely to have learning disabilities.
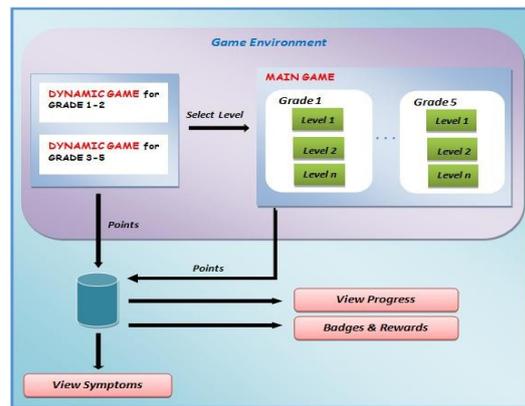
3.2 System Overview

Fig. 1. System Diagram

The system consists of two major parts, namely dynamic game and the main game, which run in a gamified learning environment.

3.2.1 Dynamic Games

This is a game, which is used to measure the current knowledge status of primary children with ADHD at the very first time login to the site. The challenges introduced in the dynamic game are mainly addressing to the symptoms of ADHD. To check the first symptom the game builds with an object memorizing technique. The game for the second symptom is a story based one. For the third and fourth

symptom the game was built with a small puzzle and some mathematical calculations to check the mental effort of the child. They are created according to the teaching techniques for the primary children who are suffering with ADHD. The main objective of using a dynamic game is to identify the current status of the knowledge and the symptoms which can be seen from the child who logs in to the system for the very first time. After playing the dynamic game, the child is evaluated and redirected to the relevant level in a relevant stage by considering the current knowledge level and the age of the child. Evaluation of the child is done by using the algorithms.

3.2.2 Main Game

This is the game, which contributes to improve the child's knowledge on mathematics in an interesting manner in a gamified learning environment. For a grade, there are three stages, and each stage contains three levels each of which are separate games. Each game was built like a story and there are limited numbers of questions throughout the game, made according to the syllabus and relevant to the story. The questions cover all the topics of the syllabus that has specified for each grade. According to the gamified leaning environment, when a child completes a level successfully, he is got unlocked to the next level and the child gets a reward according to the points he collects from the challenges he faced. At the same time, the child is gets a cartoon clip as a motivation. When the child successfully finished the three levels, he can finish a stage and can move to the next stage. There also, the child receives a badge according to the rewards he collects and at the same time, the child can get a mini video clip or a mind refreshment game as a motivation. Progress of the child can be evaluated after performing the main game.

3.2.3 Evaluation Algorithm

The child is evaluated mainly in two occasions. The first one is; after playing the first dynamic game. Current status of the knowledge on mathematics is measured at the very first login to the site. The second one is; after playing the second dynamic game. When the child finishes playing the main game, the child is redirected to play the second dynamic game. That measures, the improvement of the child after playing the main game. There are three main tree structures to evaluate the child. The algorithms developed considering the main features of ADHD and their symptoms. According to the researched data;

− *Inattention*
    a - Fails to give close attention to details or makes careless mistakes.
    b - Does not seem to listen when spoken directly.
    c - Avoids, dislikes engaging in tasks that require sustained mental effort.

    d - Has difficulty in organizing tasks and activities.
− *Hyperactivity*
    p - Leaves seat in a situation where remaining seated is expected
    q - Fidgets with hand or feet or squirms in seat
    r - Runs about or climbs excessively in inappropriate situations
− *Impulsivity*
    x - Interrupts or intrudes on others
    y - Has difficulty in waiting for an opportunity to do or use something.
    z - Blurting Answer before Question

By using the statistics of the survey of "Learning difficulties in primary children attending a special clinic at the Lady Ridgeway Hospital" [4] and the values that the researchers collected by the oral interview with five psychiatrics from one of the leading children' hospitals in Sri Lanka, the values are applied for the tree structures. The table [Table 1] shows the analyzed data that the researchers collected through verbal interviews with five psychiatrics from one of the leading children's hospitals in Sri Lanka.

All the above mentioned symptoms are using as the parameters of the bellow table. Also the inverted parameter (ex: a-a') are using for the inverse of the pervious parameters.

TABLE 1
SUMMARY OF FOCUS GROUP INTERVIEW FOR RATING ADHD SYMPTOMS -
According to Psychiatric clinic of leading children's hospital in Sri Lanka

	Inattentiveness								Hyperactivity						Impulsiveness					
	Fails to give close attention to details or makes careless mistakes	Does not seem to listen when spoken to directly	Avoids, dislikes to engage in tasks that require sustained mental effort	Has difficulty in organizing tasks and activities				Leaves seat in situation in which remaining seated is expected	Fidgets with hand or feet or squirms in seat	Runs about or climbs excessively in inappropriate situations		Interrupts or intrudes on others	Has difficulty in waiting for turn	Blurting Answer before Question					
	a	a'	b	b'	c	c'	d	d'	p	p'	q	q'	r	r'	x	x'	y	y'	z	z'
D1	8	2	7	3	5	5	6	4	8	2	9	1	8	2	3	7	1	9	2	8
D2	7	3	8	2	9	1	10	0	5	5	6	4	10	0	2	8	2	8	1	9
D3	10	0	8	3	7	4	2	9	10	1	5	6	7	4	8	3	8	3	6	5
D4	9	2	5	6	5	6	10	1	5	6	7	4	3	8	9	2	4	7	6	5
D5	7	1	7	1	8	0	2	6	7	1	7	1	5	3	0	8	3	5	1	7
	41	9	35	15	34	16	30	20	35	15	34	16	33	17	22	28	18	32	16	34
	82%	18%	70%	30%	68%	32%	60%	40%	70%	30%	68%	32%	66%	34%	44%	56%	36%	64%	32%	68%

According to Psychiatric clinic of leading children`s hospital in Sri Lanka

The data is collected through verbal interviews with five psychiatrics. According to the data collected from the doctors, inattentiveness is the major feature of ADHD. Hyperactivity comes as the second significant feature and impulsiveness is least prominent among all. It shows when doctor1 checks symptoms of impulsiveness, for the symptom 'x' he found 3 positive children and 7 negative. At the same time for the symptom 'y' he caught 1 positive child and 9 negative children.

By analyzing the data, the research team has found that the children who are suffering from ADHD are mainly having the problems in attention. Because of that reason the team decides to prioritize the inattentiveness in the challenges of the games. The bottom line of the table shows the final finding of having

and not having the each symptom among the children who are diagnosed by all five doctors on that particular clinic day. In addition, the percentages are visualized. There are some children who are suffering from one or more symptoms of inattention who also are suffering from one or more symptoms of hyperactivity. There may also be some children who are not suffering from any symptom of inattention but the symptoms of hyperactivity or impulsivity or both. Some are having all.

The researchers developed 'tree structures' for each main feature selected from ADHD to illustrate these in very clear manner. The trees finally give a unique value that allows the system to identify the combination of symptoms that a child is having. A single symptom is divided into two sub categories. They are the positive side and the negative side of the same symptom. The values (weights) of the tree branches are marked by using the statistics of the survey of 'Learning difficulties in children attending a special clinic at the Lady Ridgeway Hospital'.

Although there are three main features of ADHD, they are inattention, hyperactivity and impulsivity, the system uses only two features for the algorithm to evaluate the child. They are inattention and impulsivity. Because through the interview that the researchers had with the psychiatrics, they came to a point that hyperactivity behaviour of a child cannot be measured through their academic work. That should be measured by examining the children's day-to-day activities. Therefore, the symptoms of hyperactivity will not be addressed by the challenges of the games.

2.3.4 Equation for Evaluating a Level

$$\text{Score for a Level} = \left(\begin{array}{c} \text{Contribution from the total} \\ \text{time to complete the level} \end{array} \right) * \left(\begin{array}{c} \text{Contribution from no} \\ \text{of times repeats to} \\ \text{complete the level} \end{array} \right) * \left(\text{Full marks} \right)$$

$$\text{Score for a level} = \left(\frac{T}{T_x} * \left(\frac{4 - N}{4} \right) \right) * M$$

An equation is designed by the research team to evaluate the progress that the child has achieved in a certain level. There are mainly four parameters.

T = Theoretical minimum time spent to finish the level (in seconds)
T_x = Time spent to finish the level (in seconds)
N = Number of times repeated the level
M = Maximum marks can be achieved from the level

Theoretical minimum time allocated to finish a level (T) is a fixed value for a specific level which T_x is always greater than T. Time spent to finish the level (T_x) varies according to the child's performance. Maximum mark for a level (M) is different for level to level, because the marks allocation is different from each part. Number of times repeated the level (N) is varying from the performance of the child. Therefore

T/T_x will become lesser value, when the child spent more time to finish the level. There are three conditions considering N. They are; maximum number of times that a child can be repeated a level is 4, if N=0 and T_x=T, he is getting maximum score which is M and if N>4, he will be getting score as 0. Therefore as a result of this, it can be proved that to achieve highest score for a particular level, child has to finish the level in its minimum time with no any number of times of repeating the level.

3.2.5 By Vygotsky's Theory

The research team used the theory of Vygotsky for the system implementation. Vygotsky posited a concept of the Zone of Proximal Development (ZPD) [21]. The ZPD is the difference between what the child can achieve on its own and what it can achieve with help from others. Crossing the ZPD is essential to Vygotsk's theory. This can only be accomplished with help from More Knowledgeable Others (MKO). MKO could be a peer, sibling, a younger person, or even a computer. Through the system teachers can provide motivation to the children with ADHD as well as Primary children with ADHD can be benefited by using this system in their studies.

4. RESULTS AND DISCUSSIONS

The research was specially focused on using 'Gamified learning' concepts for primary children with disabilities. While there are several authors who reported the potential of games as valuable learning tools there is a need for further research on its real effects on learning processes and if those effects are better than those obtained with the traditional ones. In this area of study, the research explores how to incorporate the distinctive elements from games with the aim of applying them to learning environments of primary children with ADHD. Finding how to apply gamification in education, and validating proposed application is the main goal of the work. Since new application is collaborative space virtually available everywhere, from a personal computer, a laptop or a mobile device, any gamified learning activity proposed by a teacher is also ubiquitous, meaning that children can perform the activity in school or outside school. The proposed gamification environment is evaluated, with overall positive results. Usability and user experience were tested with classes (children from grade 1- 5) in different schools. According to those result, some features that were evaluated negatively were corrected and several improvements were introduced in the interface. With the evidence from this study, research team produced this list of current best practices for games used for learning:

- Rewards must be explicitly recognized in the social context to make them meaningful; the more explicit this recognition among the learner's peers, the stronger the motivation to continue will be.

- Immediacy of feedback is an important motivational element. As a result, rewards must be immediate; test grading must therefore also be immediate.
- Game rewards must be matched to difficult but attainable learning tasks. Some research even suggests that the best way to engage children with a game is to confuse them first. Confusion leads to increased engagement. But be careful not to make the game too difficult, or children will simply give up.

5. CONCLUSION AND FUTURE WORK

The team believes that the design and implementation of both the underlying infrastructure for tagging/storage and the resulting visualizations and methods by which they are generated have been extremely successful.

The project team provides a platform with better facilities for children with learning disabilities, to facilitate their thirst of education. Primary goal of this research is to develop an interactive gaming environment for children who are with ADHD to learn mathematics in an attractive way. 'Gamified Learning Environment for the Children with Special Needs in Primary Schools' system covers a wider area. It provides a better solution for the learning problem of the child. Until now, a lesser number of researches have been done in this area in Sri Lanka.

Project team hopes this system will be a revolution of the primary education sector in Sri Lanka and the system covered most of the intended milestones. The team expects to improve the presented system as a Mobile application that can be used through the smart phones and tablets with an android platform. This will allow the working parents to monitor their children's learning without being location restricted. The application installed in a mobile device will become very effective and engaging game for the children. Parents can do payments through the mobile. The use of ad hock network is having the ability to connect teachers with the child's activities in the system. The child can play the game as multi player game via ad hoc network. The teachers can advice a group of children to get together and play the game in front of the teacher. Then the teacher can view the child individually on her desktop and has the ability to help the child through the network as voice instructions or visuals.

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