

Technological Aids for Dyscalculic Children

Mrs. Nisha Vanjari^[1]

Professor, Computer Engineering Department, K. J. Somaiya Institute of Engineering and Information Technology, Mumbai, India.

nvanjari@somaiya.edu[1]

Ms. Snehal Bakre^[2], Mr. Ronak Parmar^[3], Ms. Vidhisha Singal^[4]

Undergraduate Student, Computer Engineering Department, K. J. Somaiya Institute of Engineering and Information Technology, Mumbai, India.

snehal.bakre@somaiya.edu[2], ronak.parmar@somaiya.edu[3], vidhisha.s@somaiya.edu[4]

Abstract— *Dyscalculia is associated with the child's inability to understand the basic mathematical concepts. Dyscalculia covers a variety of challenges in mathematics that include understanding the numbers which are the root of mathematics to the inability to grasp the mathematical language. Hence, for such kid's dealing with mathematics even in day to day life is a challenging aspect and even more difficult if they have no tools that would be an aid to their disability. Although there are many interactive learning techniques, most of the time students tend to lose interest so learning in the form of game can be helpful and can enhance learner's motivation. The process of learning through games is known as gamification. The main aim of gamification is providing a technological aid to support students suffering from dyscalculia. Understanding of gamification is an important task as playing video games and games are considered as tasks for entertainment purposes, so it is not considered as an aid in learning. So, gamification awareness is very important, to be considered as an aid to teach children suffering from dyscalculia.*

Keywords— *Educational games, dyscalculia, distance education, gamification*

I. INTRODUCTION

Of the many different types of learning disabilities dyscalculic is also a learning disability associated with the difficulty in understanding mathematics. Difficulty in dealing with mathematics not only impacts the child's schooling but also the child may face difficulty in doing day to day tasks. For instance a dyscalculic may find it intimidating to understand the difference between the number 6 and the word six associated with it. So it is very important to understand the kind of challenges the child is facing in order to help the child overcome it's disability. Many tools are available to guide the child into dealing with the fear of mathematics. The parents also need to understand the exact issues their kids are having. Technology has evolved in various ways over the years. Classroom learning evolved to e-learning. But both these methods are not that effective for children with dyscalculia. To

help such students, gamification was developed. The four main goals of e-learning include increased effectiveness, efficiency, engagement and motivation in students is achievable by gamification. Gamification helps to motivate the child to actively participate in the classroom activities as it makes the learning fun and easy. Gamification is basically a way in which humans learn. Understand the target audience, define the learning objective, structure experience, identify resources and apply gamification elements are the five steps of gamification.[1]. Studies suggest that the recall rate is 10% and 90% for verbal and image simulation, respectively after 72 hours. Therefore, use of games can prove to be very effective for retaining knowledge[3]. For assisting such students, a swift playground calculator, Chocolorator was developed [2]. Another approach to help dyscalculic children is a clinical method wherein tests are provided to the child. These tests consist of a specific kind of questions to find out the area in which the child lags [4].

II. METHODOLOGY

In order to understand the various topics involving dyscalculia, we performed a step by step review of the same. In order to facilitate the review procedure, we explored the internet and also various reference books, one of which was WJ IV test manual that explains various tests which helped in deciding if the child has dyscalculia or not[35]. On the internet, various research papers, websites, journals, books were explored with the help of following keywords- gamification, dyscalculia, learning disabilities, game based learning, which basically helped us study dyscalculic children and in turn helped in our research process step by step.

III. RESULT AND DISCUSSION

A. Understanding dyscalculia

Dyscalculia is a greek derivative that is associated with a person's inability in understanding mathematics (dys - bad +

calculia - calculate). The child from a very young age starts showing the signs of dyscalculia meaning they start struggling with day-to-day activities like counting or distributing things. The basic signs of dyscalculia or the difference between normal child and the dyscalculic child are -

	Normal Child	Dyscalculic Child
Task	Able to do	Able to do
Counting Objects	Yes	No
Make comparisons	Yes	No
Performing mathematical operations	Yes	No
Reading mathematical symbols	Yes	No
Sequencing of numbers	Yes	No
Classify 3D and 2D objects/ tell directions	Yes	No

Based on the area of difficulty dyscalculia is classified into various categories -

Category of dyscalculia Problem associated with it

- 1. Verbal dyscalculia: Inability in understanding the mathematical concepts said verbally or the inability to talk about the same.
- 2. Ideognostic dyscalculia: Inability in figuring out the task required to understand mathematical relationships.
- 3. Practognostic dyscalculia: Inability to connect the mathematical concepts with real world concepts.
- 4. Lexical dyscalculia: Inability to read numbers and understand them if they occur in sentences.
- 5. Graphical dyscalculia: Inability in writing mathematical concepts or even numbers.
- 6. Operational dyscalculia: Inability in performing any kind of arithmetic operations for manipulating numbers.

[26].

Although the exact reason of dyscalculia is unknown researchers believe two main causes of dyscalculia -

- > **Genes and hereditary** - Various types of genetic disorders like Turner's syndrome, Fragile X syndrome, Velocardiofacial syndrome, Williams syndrome can be the cause of dyscalculia. Also it is believed that dyscalculia can also be inherited.
- > **Brain development** - There are some differences in the brain imaging of dyscalculic child and normal child [27].

B. Understanding the human brain

The human brain is very complex when it comes to processing everyday activities. The uniqueness in the person's personality is due to the functions that the cerebral cortex which is one of the parts of the human brain performs. Cerebral cortex is mainly divided into four lobes namely, the frontal lobe, parietal lobe, occipital lobe and the temporal lobe (see Fig No. -1). These four lobes are responsible for carrying out various reasoning and logical functionalities -

- > **The frontal lobe-**
 - 1. Location: Front of brain
 - 2. Function: High level cognition, reasoning, expressive language and motor skills.
- > **The parietal lobe-**
 - 1. Location: Middle section of brain
 - 2. Function: Processing information of tactile senses such as touch, pain and pressure.
- > **The temporal lobe-**
 - 1. Location: Bottom section of brain
 - 2. Function: Interpreting sounds and language.
 - 3. Beras hippocampus which is associated with emotions.
- > **The occipital lobe-**
 - 1. Location: Back of brain
 - 2. Function: Processing of visual stimuli

Study has been carried out to understand the connection between the problem associated with dyscalculia and the cerebral cortex related to it [7][5]. Also Studies conducted on non dyscalculic people have shown that the right intraparietal sulcus (IPS) is related with the mathematical processing. The dyscalculic has an impaired IPS which is why their brain cannot process the numerical processing efficiently [6].

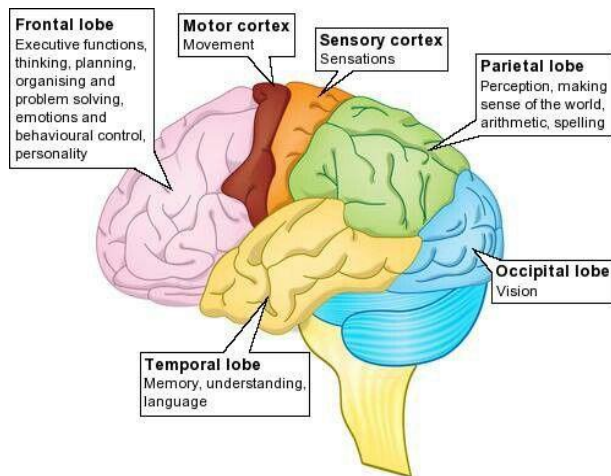


Fig. 1. The lobes of the Brain

As estimated, 7% of the population suffers from dyscalculia, which means that people in this 7% of the population have normal intelligence but face severe difficulties in problems or activities involving numbers.

The maximum time spent by the child is either with their parents or the teachers. So, if any of them gets to know that their child is facing an issue, they can be immediately taken to a doctor to get solutions to the problems being faced. So, understanding the perspective of parents as well as teachers' sides is very important.

C. Parents' and Teacher's Perspective

Parents and teachers face difficulty in dealing with children with dyscalculia as they on their own are unaware about the symptoms, treatment methods and the behavioural aspects of the child. The main limitation faced by teachers and parents is that they do not get the necessary information or feedback regarding the child's progress, thereby, delaying the process of improving the child's capability to deal with mathematical problems. At times, parents are unaware about the fact that their child is suffering from dyscalculia as they lack a proper set of guidelines that would help the parents identify the mathematical issues related to their child. A set of basic mathematical questions that are most commonly solvable by all the students of their ward's age would in a way help the parents get a hint of the child's disability.

There are many problems faced by dyscalculic children out of which some are they cannot cope up with the speed of a normal child. They tend to lose confidence very easily. Observing the child can help the parents, teachers and doctors to develop various strategies to support the child in reducing the problem of dyscalculia. Numerous tools are developed to help the dyscalculic child such as the Fountain Valley Teacher Support System in Mathematics, Stanford Diagnostic Mathematics Test. Some other tests are Diagnostic Test of Arithmetic strategies which are for children of age 0 to 12

years, which gives instruction on how to deal with children suffering from dyscalculia.

The newer and updated approach in the technology field to help the child suffering with dyscalculia is the Dyscalculia Screener. The software was basically build for children of 6-14years of age group and was used by teachers to evaluate whether the child showed any signs of dyscalculia based on a set of questions that would help them identify the weaker mathematical areas of the child and if there were any then help the teacher provide help to the child online [8].

Some students have lifelong learning disabilities and they need special attention and help from specialists as well as teachers. But, teachers always do not have time to consult a specialist or find out ways to help the child. So, a software was developed to help teachers through which they can make decisions specifically for each child. And this software tells whether the decision is correct or not[14].

Every child has a different way of learning and grasp concepts in a different way. Mixed Reality(MR) is a platform that offers teachers ways to engage children to learn the concepts of mathematics. This also helps in developing the child's interest [15].

D. E- learning and Game Based Learning

Traditional methods like blackboard learning are ineffective for a child suffering with dyscalculia. Also, in traditional teaching methods, the attention of the teacher used to get shared among many children. So, attention needed by a specific child was never provided. To overcome this problem of teaching, integration of traditional methods with technology is done.

Edgar Dale's learning cone helps us in understanding how much a person can remember after reading, listening and understanding concepts of various studies. The Edgar Dale's cone states that any work done practically along with proper visualization is retained by the brain for a longer duration (see Fig No. -2).

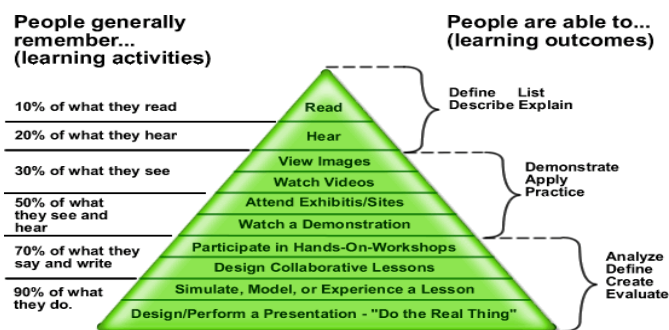


Fig. 2. The Edgar Dale's pyramid

So a visual aid to assist the learning methodology is E-learning. A study was conducted to determine whether the students prefer e-learning or traditional learning of which the

finding indicated that the students preferred the former [28][29]. The major problem with e-learning is that the attention span of a normal human is less than 5mins and since the problem with dyscalculic children is that they are disinterested in learning e-learning alone cannot aid as an help to these kinds of kids.

Another visual aid towards learning is the game based learning. Game based learning provides a game based perspective to students in understanding the concepts through a gaming which is basically designed by the teachers. By collecting feedback from the students, the teachers can work towards improving the game in order to achieve its goal by making necessary changes.[12]. Game based learning can also be done with the help of mobile applications. Use of such mobile applications can help in improving the child's math solving ability [3]. Game based learning has proven effective. A study was conducted in which students with intellectual disability had participated. And playing games was an effective method to help the students in solving math problems [9][11].

Students have a lot of interest in playing games. So, this advantage will help to improve the learning process which will eventually help them to improve the condition of dyscalculia. Also, a web based application was developed for such students with mixed methods for gathering insights as to how to engage these students to learn math and for analysing how their development took place using these educational games [10]. A series of games to be constructed for students should follow proper design guidelines and game design frameworks [13].

But the problem with game-based learning, the child gets addicted to the device or gets hooked up on games. Also there was no particular way of keeping track of the performance of a child. So, the teacher was unable to get updates about the child. So, to avoid such problems gamification was developed.

E. Adaptive Gamification as an aid for dyscalculic children

Gamification is the process of adding games to a task so as to make it more interesting to participate. Gamification is the best solution to engage users to play games to improve the users' knowledge about a particular topic. Designers should design games which make it more playful and engaging for the users to play. Games should be developed in such a way which are useful for every user as each user has different needs and ways to play games [24].

Today's learners belong to a digital era. So, making this generation learn with the help of gamification will increase the learner's motivation and focus towards learning concepts[17]. In the past couple of years, gamification usage increased in education. An online toolkit, Kahoot was used to analyze the gamification usage. This method of involving gamification in education motivated students to learn various educational concepts[18]. An assistive method for final project development which was based on gamification

named, GAMED, was developed for high school students to various aspects such as motivation, teamwork and engagement this was done by bringing various game elements to school. This helped the high school students to reduce the stress of final course projects[21].

Gamification helps children with normal intelligence to improve their concepts of various topics. In addition to a child with normal intelligence, gamification has also helped children with special educational needs to learn and improve concepts of various educational topics[3].

Augmented Reality[AR] in integration with gamification is also used to help people with intellectual disabilities learn[22]. Different types of math tools are developed to teach the concepts of mathematics such as counting, arithmetic operations, smaller and greater, numbers etc that make use of gamification for the dyscalculic children[23][24][25].

In Spite of gamification being effective it does not adapt to the needs of the learner. Adaptive technology can prove to be better aid for the students to learn [30][26]. The game tailored according to the needs of a student following the design paths and principles help to develop a technology more effective than the non adaptive gamification types [31][33].

A model was developed with the help of machine learning to predict performance. This model is the personalized adaptive gamification which has proved helpful for an individual to improve their performance and motivation. Methods are developed to find out about the emotion of the individual which will help in improvement of the performance as well as motivation [32].

Over the last decade, the field of gamification is growing at a huge rate. Gamification usage has helped the learner's in a positive way. A project named LudiMoodle, aims at finding out new information about the specific elements of a game such as scores, progress etc with the help of a digital learning environment. This project helps the researcher with adapted game elements according to each and every profile of the learner[34].

Since adaptive gamification is more focused on the need of the user it can be a good aid for students with learning disability. Since these children have special educational needs and their area of weakness may differ from child to child adaptive gamification can help assist and monitor the child's progress on an individual level.

ACKNOWLEDGEMENT

We would like to thank the Maharashtra Dyslexic Association for their help in giving us a brief idea about the way of thinking of dyscalculic children. We would like to express our sincere thanks to our principal sir, Dr. Suresh Ukarande. We would also like to thank our guide Ms. Nisha

Vanjari for her guidance at each and every step of the project. We would like to extend our thanks to our H.O.D. Ms. Sarita Ambadekar.

IV. CONCLUSION

Dyscalculia is a learning disability which can be improved with the help of various technologies and tests which are developed over the time. Some of the technologies and tests which help in improving the condition of dyscalculia are-Fountain Valley Support System, Stanford Diagnostic Mathematics test. Softwares such as Dyscalculia Screener Digital were developed for the teachers to help them to evaluate the tendencies of a child with dyscalculia. Adaptive gamification can be used as an aid for a dyscalculic child over game based learning and traditional methods of learning. We have also discussed the doctor's, teachers and parents' perspective about a child suffering from dyscalculia. And also what measures can be taken to help the child in improving the mathematical concepts.

REFERENCES

- [1] Mhd. Rizky Ferianda, Anisa Herdiani, Indra Lukmana Sardi, "Increasing students interaction in distance education using gamification", 2018 6th International Conference on Information and Communication Technology (ICoICT).
- [2] Erick Lozano Borges, Pedro Henrique Cacique Braga, Ilana de Almeida Souza Concilio, "Application to help the learning process of children with dyscalculia", 2018 XIII Latin American Conference On Learning technologies.
- [3] Pinedo Rivera Dafne Ifigenia, Muñoz Arteaga Jaime, Broisin Julien, Ponce Gallegos Julio Cesar, "Integration of gamification to assist literacy in children with special educational needs", 2018 IEEE Global Engineering Education Conference (EDUCON).
- [4] Andrea Biancardi, Rita Francese, Michele Risi, Mario Procida, "DyscalcTest generation environment: supporting the clinician in the creation, delivery and evaluation of dyscalculia tests", 2019 23rd International Conference Information Visualisation (IV).
- [5] Kadosh, R. C., Kadosh, K. C., & Henik, A., "When brightness counts: The neuronal correlate of numerical-luminance interference", *Cerebral Cortex*, 18(2), 337–343.
- [6] Cohen Kadosh, R., Cohen Kadosh, K., Schuhmann, T., Kaas, A., Goebel, R., Henik, A., & Sack, A. T., "Virtual dyscalculia induced by parietal-lobe TMS impairs automatic magnitude processing", 2007, *Current Biology*, 17(8), 689–693.
- [7] Antonia, P., Catherine, B., & Panayiotis, V., "Cognitive science: From molecular biology to brain function", 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA).
- [8] Filipa Ferraz, José Neves, "A brief look into dyscalculia and supportive tools", 2015 IEEE International Conference on E-Health and Bioengineering.
- [9] Brown, D. J., Ley, J., Evett, L., & Standen, P., "Can participating in games based learning improve mathematic skills in students with intellectual disabilities?", 2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH).
- [10] Piki, A., Markou, M., & Vasiliou, A. ,” Learning through play: The role of learning and engagement theory in the development of educational games for intellectually challenged children.”, 2016 International Conference on Interactive Technologies and Games (ITAG).
- [11] Cano, A. R., Garcia-Tejedor, A., Alonso-Fernandez, C., & Fernandez-Manjon, B, "Game analytics evidence-based evaluation of a learning game for intellectual disabled users", 2018 IEEE Access
- [12] [online] Available at: <https://edtechreview.in/dictionary/298-what-is-game-based-learning> .
- [13] Tsikinas, S., & Xinogalos, S., "Designing effective serious games for people with intellectual disabilities", 2018 IEEE Global Engineering Education Conference (EDUCON).
- [14] Tahan, O., & Barake, F., "A gaming environment to train teachers diagnose children learning disabilities."2018 14th International Computer Engineering Conference (ICENCO).
- [15] Aljowaysir, N., Ozdemir, T. O., & Kim, T., "Differentiated learning patterns with mixed reality", 2019 IEEE Games, Entertainment, Media Conference (GEM).
- [16] Codish, D., & Ravid, G.,"Adaptive approach for gamification optimization.", 2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing.
- [17] Gabriela Kiryakova , Nadezhda Angelova , Lina Yordanova, "Gamification in education"
- [18] Vranesic, P., Aleksic-Maslac, K., & Sinkovic, B., "Influence of gamification reward system on student motivation", 2019 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO).
- [19] Ferianda, M. R., Herdiani, A., & Sardi, I. L, "Increasing students interaction in distance education using gamification", 2018 6th International Conference on Information and Communication Technology (ICoICT).
- [20] Cheng, C.-H., & Su, C.-H., "A Game-based learning system for improving student's learning effectiveness in system analysis course", *Procedia - Social and Behavioral Sciences*.

- [21] Souza, P., Mombach, J., Rossi, F., & Ferreto, T., "GAMED: Gamification-Based Assessment Methodology for Final Project Development", 2019 IEEE 19th International Conference on Advanced Learning Technologies (ICALT).
- [22] Colpani, R., & Homem, M. R. P., "An innovative augmented reality educational framework with gamification to assist the learning process of children with intellectual disabilities", 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA).
- [23] [online] Available at: <https://www.cognifit.com>
- [24] [online] Available at: <https://www.theusabilitypeople.com>
- [25] [online] Available at: <https://www.dyscalculia.org>
- [26] [online] Available at: <https://dopasolution.com/dyscalculia>
- [27] [online] Available at: <https://www.understood.org>
- [28] Alaneme, G. C., Olayiwola, P. O., & Reju, C. O., "Combining traditional learning and the e-learning methods in higher distance education: Assessing learners' preference", 4th International Conference on Distance Learning and Education. (2010).
- [29]. Costa, L., Souza, M., Salvador, L., & Amorim, R., "Monitoring students performance in e-learning based on learning analytics and learning educational objectives", 2019 IEEE 19th International Conference on Advanced Learning Technologies (ICALT)
- [30]. Lavoue, E., Monterrat, B., Desmarais, M., & George, S., "Adaptive gamification for learning environments", 2018 IEEE Transactions on Learning Technologies.
- [31] Hallifax Stuart, Audrey Serna, Jean-Charles Marty, Elise Lavoué, "Adaptive gamification in education: A literature review of current trends and developments", 2019 European Conference on Technology Enhanced Learning (EC-TEL), Delft, Netherlands.
- [32]. Christopher Lopez, Conrad Tucker, "Towards personalized adaptive gamification: A machine learning Model for predicting performance", 2018 IEEE Transaction on Games.
- [33]. Martin Böckle, Isabel Micheel, Markus Bick, Jasminko Novak, "A design for adaptive gamification application", 2018 51st Hawaii International Conference on System Sciences.
- [34] Élise Lavoué, "LudiMoodle: Adaptive gamification to improve learner motivation", 2019 Université Jean Moulin Lyon.
- [35] Kevin S. McGrew, Erica M. LaForte, Fredrick A. Schrank, "Woodcock Johnson IV", Technical Manual