Prototyping a Mobile Application for Children with Dyscalculia in Primary Education using Augmented Reality

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***Abstract*—Dyscalculia is a disorder of difficulty in understanding, understanding of numbers and mathematical operations in such a way that the child has a greater stress by not solving the exercises proposed by the teacher, leading to the objective of the research in making an innovation plan dedicated to the mobile prototype with augmented reality for children with dyscalculia in primary education. Design Thinking was used as a methodology that allows us to know the needs of users and implement new solutions to their problems, so that the project team makes decisions to choose the best idea proposed, likewise this idea must be applied to a model or design, for this the Miro application was used for the mobile prototype, for the 3D design TinkerCad was used for educational games and finally the App Augmented Class application that was responsible for the visualization of augmented reality. The results were obtained through interviews with parents, indicating that the mobile prototype with augmented reality is a great contribution of impact and should be applied for children, finally this prototype is validated by five experts who mentioned that the final prototype has 86% acceptance. The conclusion of this research is to make an innovation model to solve the problems of dyscalculia, improving understanding and comprehension in mathematics.**

Keywords*—App augmented class; design thinking; dyscalculia; miro app; TinkerCad

I. Introduction

Dyscalculia is a disorder that demonstrates learning difficulties in understanding, learning and performing subjects involving mathematical numbers, and also affects reading and writing, as well as attention deficits and visual problems [1]. Dyscalculia exists in every 5-8% of children in schools worldwide with symptoms of this disorder [2], in schools in India, between 13% and 14% of school-aged children are reported to have these learning disabilities. In such a way that covid-19 also influences the process of this disorder in school children when virtual classes are established, students do not have a monitor to guide them in their educational process, and children with symptoms of dyscalculia tend to be easily distracted [3].

In Latin America there are learning difficulties in children in such a way that the teaching of mathematics has a low performance of 49.9% to 70.3% and in this way the schools do not provide a good quality of teaching in their schools, considering a serious problem for dyscalculia to indicate the low preparation in education regarding mathematics is why children do not have highly trained teachers to provide good teaching [4]. In Brazil, which considers that dyscalculia impairs school performance and achievement in mathematical operations [5], it also considers that out of every 304 schoolchildren aged 7-12 years of both sexes are assessed and 22 children are diagnosed with dyscalculia [6].

The majority of children with dyscalculia in Peru have difficulties in their academic development, thus indicating that students have teachers who are not trained to meet the needs of children [7]. In the Covid-19 pandemic, because they are not prepared to establish virtual classes, they do not have enough materials to carry out their activities, which is a big problem for many students, especially in rural areas of Peru, where they have problems in mathematics [8][9]. This is why the level of stress in children with dyscalculia can greatly affect their concentration to perform their activities [10].

These problems have been identified in the world, and we can see the need for a strategic plan to solve the problems related to dyscalculia, so that students with these disorders can improve their understanding and comprehension of subjects, strengthening their attention span. Proposing this solution for children with dyscalculia is affecting education in Peru as it requires the support of parents or teachers for its use. It also makes serious learning more affectionate as the child feels more confident to improve these learning problems.

The aim of the project is to develop a prototype of a mobile application for children with dyscalculia in primary education using augmented reality. Cognitive games or therapies will be made to solve mathematical problems with certain learning levels, in order to capture the attention of children with dyscalculia. The structure of the following: in Section II the literature review is explained, in Section III the methodology to be developed, in Section IV the results of our work, in Section V the discussions, in Section VI the conclusions and finally in Section VII the future work.

II. Literature Review

Augmented reality in mobile applications for the treatment of dyscalculia or strengthening skills in education meets the expectations to improve learning. So they implement augmented reality to help students with dyscalculia to perform their activities in the subject of arithmetic, fulfilling learning in addition, subtraction, multiplication and division [11]. They also carry out an evaluation of children with dyscalculia and how it interacts with augmented reality since it indicates that the use of these technologies such as augmented reality draws the attention of students and facilitates the understanding of mathematical activities [12]. The educational plan to use augmented reality has many advantages that will help teachers to understand the problems of children with dyscalculia also involves the dedication and patience it takes this process since they claim in their research that 92% of students interacting with augmented reality, improves their ability to understand [13].

Similarly, augmented reality in mobile applications can be more effective as people have a mobile phone in their homes giving them the opportunity to transmit education from the mobile application using augmented reality, as well as children with problems are treated with the help of their parents or loved ones without the need to have a specialist for these problems [14]. That is why this research makes a mobile prototype with augmented reality, giving a simulation of learning for children with learning disabilities, fulfilling the objective of helping them to perform their activities of their subjects in their respective classrooms [15]. For this reason, they indicate that the mobile application is very effective in attracting the attention of the child with dyscalculia, making it easier for them to concentrate during the treatment process, accompanied by educational games to increase the effectiveness of the treatment [16]. In this way this research in Arequipa, Peru uses this method of creating educational video games with 3D animations in their respective implemented in a mobile application giving in conclusion that these tools are very good to improve the education of the country [17].

There are tools for the implementation of augmented reality in mobile applications, in which programmers use Unity Game for the development of games with the purpose of optimising visual and auditory learning, by using this application children with learning disabilities can improve their reading and mathematics [18]. Similarly it is understood in this research that has problems with attention and compression in their primary level students as they have low performance in their chemical activities, with the help of augmented reality helps them to understand easily also 87.90% students in Indonesia validate their improvement [19]. The analysis of augmented reality applications for dyscalculia or any problem that involves education, meets its objective of supporting their treatment or improvement in their learning, which is why they also use tools such as surveys where they indicate how valuable these innovative solutions are in education [20].

The mobile application with augmented reality indicated by the authors in this literature review, in dyscalculia as well as in education. They show the importance that are tools that they use to improve their understanding and attention in children, in such a way that applying these innovative methods can solve problems in education, science, research, business, security among others. By finding problems in education and investigating solutions in different researchers, it is proposed that in our research we propose to improve the understanding of children with dyscalculia in primary education in Peru with the help of augmented reality.

III. Methodology

For the use of the meta-logic we use the Desing Thinking that is in charge of realising creative solutions for the user, which is divided into 5 stages (Empathise, Define, Ideate, Prototype and Test), these stages have tools for their development that are explained in detail in this section.

A. Design Thinking

It is a very pleasant methodology with the aim of solving the problems of the users using innovative ideas with the use of technologies to improve the expectation of those involved [21], It is a methodology that can be carried out in a short time and it is also necessary to have the approval of the final product and possible improvements [22]. It is a methodology of great interest to improve or create new products to improve the user's lifestyle using strategies and a variety of solutions, it is highly recommended by designers dedicated to innovation [23], the steps to be followed are shown in Fig. 1.

1) Empathise: This is the first stage of the Design Thinking methodology that fulfils its objective of finding user needs and it is necessary to use information gathering techniques to identify them [24]. This is why the best way to carry out this stage is to use tools such as surveys or interviews to get an in-depth understanding of people's relevant needs [25].

2) Define: This is the second stage of the methodology, which is responsible for organising or aggregating the data from the first stage in order to identify or understand the most important user problems. To do this, it is necessary to use techniques to group and prioritise these problems [26].

3) Ideate: This is the third stage, which has the main function of producing a greater number of ideas or solutions that respond to the problems of the second stage, it is necessary that the design or innovation team has a clear idea of the problems in order to assign impactful solutions for the users [27].

4) Prototype: This is the fourth stage which is in charge of making a prototype, mock-up or design according to the impacting idea of the third stage. The prototype will serve to show the user the solution to their problem that fits their needs, for this it is necessary to use prototyping applications or as well as using physical mock-up [28].

5) Testing: This is the last stage of the methodology that fulfils the main objective of validating that the user is completely satisfied with the prototype that is the design of the solution to their problems as well as helping us to provide new improved versions of the proposed solution, it is necessary to use tools that interact with the end users [29].

B. Tools for Mobile Prototype Design with Augmental Reality

In this part it is necessary to know the tools to implement the design of the mobile application and the augmented reality model, as well as to visualise in detail the interaction of the applications that are in charge of fulfilling the objective as shown in Fig. 2.

1) Miro APP: It is a collaborative platform that its main function is teamwork in real time, is widely used for project management, has a number of free templates for efficiency and understanding of the meetings among them are mind maps, whiteboards, charts, flowcharts, wireframe web and mobile [30].

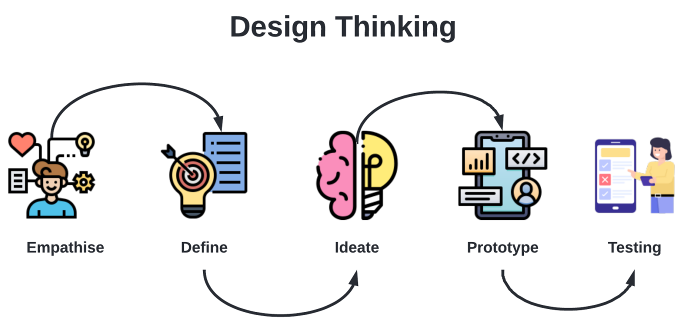

Fig. 1. Methodology Design Thinking.

2) Tinkercad: It is an application that takes care of real 3D modelling or design for free and online. It is built precisely for any user with no experience or with experience in design allowing you to create complex models [31]. It has a variety of features so that your 3D modeller can visualise using augmented reality as well as use programming for arduino circuits, import and export files, among others [32]. Tinkercad can be used in any browser as the main basic requirement for the use of the user is to have a mobile device, tablet, computer or laptop [33].

3) App Augmented Class: This application can be found in the play store for free and allows you to visualise projects with augmented reality, for which it is not necessary to have basic technical knowledge and its use is simple and intuitive. App Augmented Class has its own designs to learn about augmented reality and also add your own 3D designs [34].

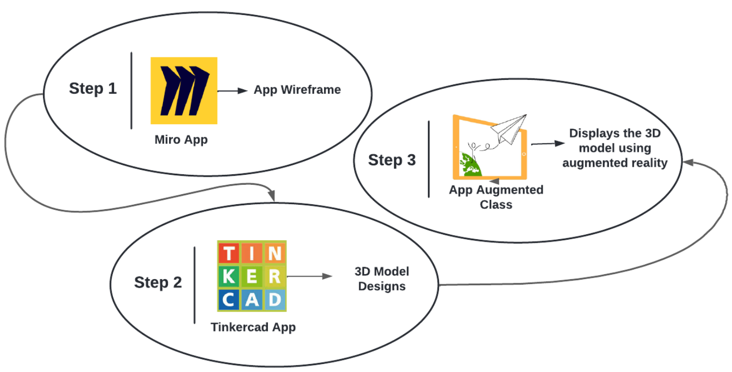

Fig. 2. Application Design Steps and Augmented Reality Modeling.

IV. Results

This section of the results shows how to develop the phases of the Design Thinking methodology that will allow us to know the problems of users and provide the solution in the short term, as well as using the proposed tools to implement mobile design with augmented reality, on the other hand will have the validation of experts who ensure the efficiency and impact that has the mobile design with augmented reality and finally will share the advantages, disadvantages and comparisons that our methodology has.

A. Results of Empathise

To understand the results of the first phase of the methodology it is necessary to identify the six questions proposed (Q1 to Q6) by the project team that are addressed to the parents, in order to find out their children's problems in mathematics as shown in Table I.

TABLE I. Questions

Questions	
ID	**Questions**
Q1	What grade is the child in?
Q2	Sex ?
Q3	In which district of Lima is the child located
Q4	Does the child have difficulties in understanding and comprehension?
Q5	Does the child experience stress when not solving the problems proposed by the teacher?
Q6	Does the child have difficulty recognising numbers?

B. Results of Define

In the results of the second phase of the methodology which is in charge of verifying the answers of the questionnaire (R1 to R6) of the parents, there are a total of 70 answers for analysis as shown in Table II.

TABLE II. Parents' Response to their Children

Answers	
ID	Answers
R1	First Grade Primary 35.7%, Second Grade Primary 15.7%, Third Grade Primary 8.6%, Fourth Grade Primary 17.1%, Fifth Grade Primary 14.3%, Sixth Grade Primary 8.6%.
R2	Male 68.6% Female 31.4%
R3	Los Olivos 28.6%,San Martín de Porres 18.6%,Carabayllo 14.3%,Lima 12.9%,Independencia 11.4%,Comas 14.3%
R4	Yes 74.3% , No 25.7%
R5	Yes 70% , No 30%
R6	Yes 71.4% , No 28.6%

a) R1: The first response which refers to the 70 respondents in which parents indicate that their children were questioned in the first grade of primary school has 35.7%, second grade of primary school has 15.7%, third grade of primary school has 8.6%, fourth grade of primary school has 17.1%, fifth grade of primary school has 14.3% and sixth grade of primary school has 8.6%.

b) R2: The responses to the second question indicate that male students 68.6% and female students 31.4% were correctly answered.

c) R3: The answers to the third question indicate the districts of Peru-Lima that have been surveyed, indicating that in Puente Piedra 8.6%, Los Olivos 27.1%, Carabayllo 28.6%, San Martín de Porres 15.7%, Comas 17.1%, Rimac 2.9%.

d) R4: The answers to the fourth question indicate that children have greater difficulty in understanding and comprehension, with 74.3% of respondents saying this is the case and 25.7% saying it is not.

e) R5: The answer to the fifth question indicates that 70% of the respondents have more stress when they do not solve the problems proposed by the teacher and 30% have a solid education without stress.

f) R6: The answer to the fifth question indicates that 71.4% of respondents have difficulty with number recognition and 28.6% do not have this problem.

C. Results of Ideate

For the results of the third phase of the methodology, plans or solutions are developed for the problems found in the surveys in Fig.3 shows the graph where the innovation developers make their score to decide which of the ideas show the greatest impact for the user, likewise the idea with the highest score is: Develop a mobile application with augmented reality.

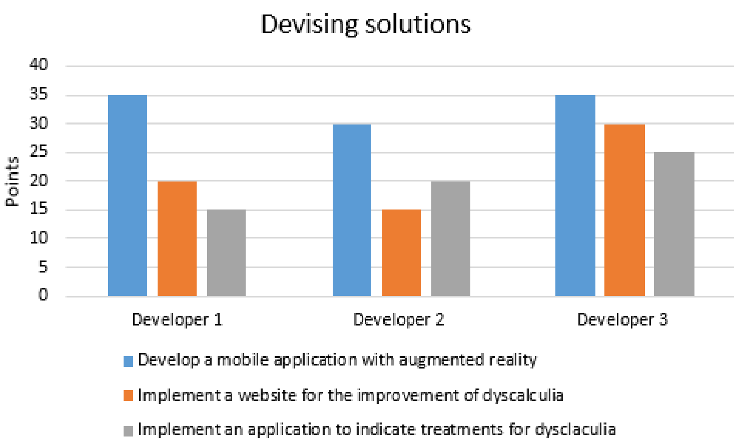

Fig. 3. Results of Idear.

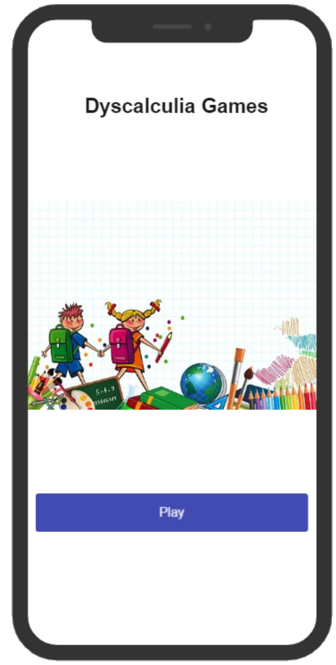

Fig. 4. Start of the Mobile Application.

D. Results of Prototyping

For the results of the prototype that was made with the tools indicated in Fig. 2, it will show the main functions that the mobile application with augmented reality will have, therefore in Fig.4 it will start with the welcome to the application to start the educational game with augmented reality where the user with dyscalculia problems must press the play button to advance with the following steps.

The second prototype refers to the selection of the child's level as shown in Fig. 5, click on the child's primary school grade and then look for the child's age, and we will continue with the next step.

Fig. 6 shows the first game to be developed for the first grade of primary school where the child can learn thanks to augmented reality with a dynamic design for better understanding and comprehension. In this way, it will have stars that indicate how the first game is developing, which tries to complete the sequence of numbers and finally the child can indicate whether he/she likes or dislikes the game.

Fig. 7 shows the addition in augmented reality so that the child can select the correct answer. The aim is not to guess the result, but to allow the child to mentally develop the sum or to have the support of the teacher to supervise the child's understanding of the exercise.

Similarly, Fig. 8 shows the same dynamics of the second game, the difference is that it shows the subtraction with augmented reality.

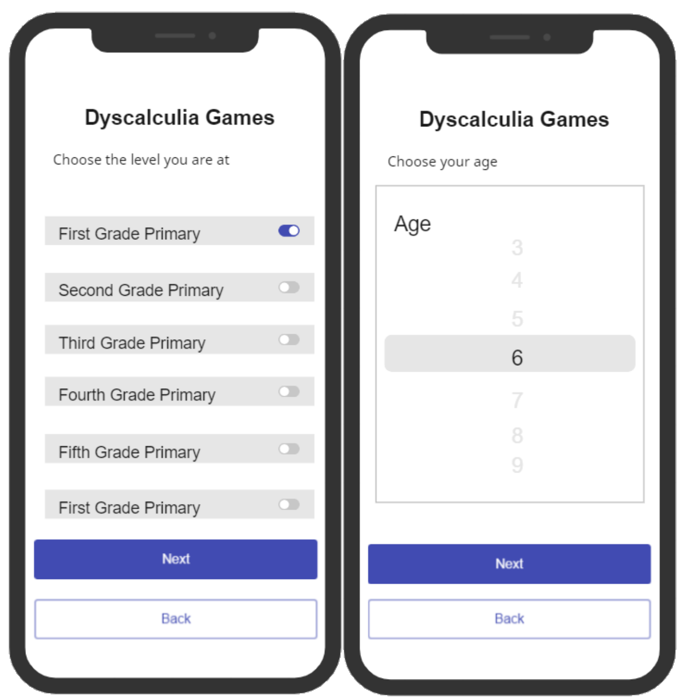

Fig. 5. Level and Age Selection.

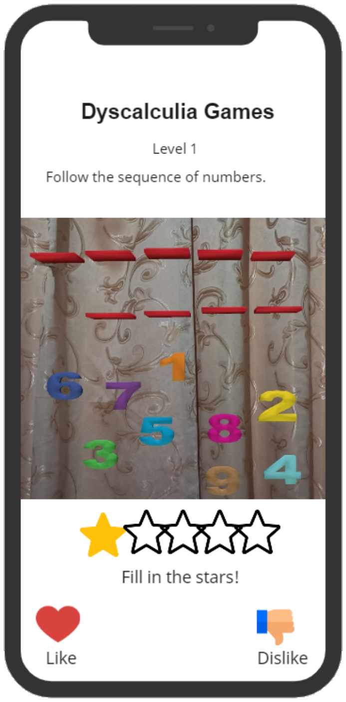

Fig. 6. First Game of the Mobile Application with Augmented Reality.

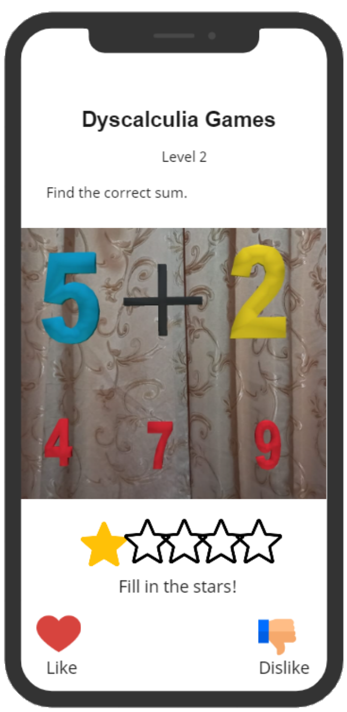

Fig. 7. Second Game of the Mobile Application with Augmented Reality.

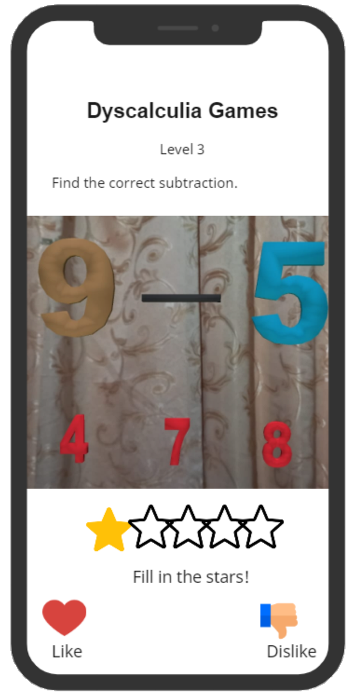

Fig. 8. Third Game of the Mobile Application with Augmented Reality.

Finally, Fig. 9 shows the game that will try to display the figures in such a way that you must identify or select the total number of figures for each row.

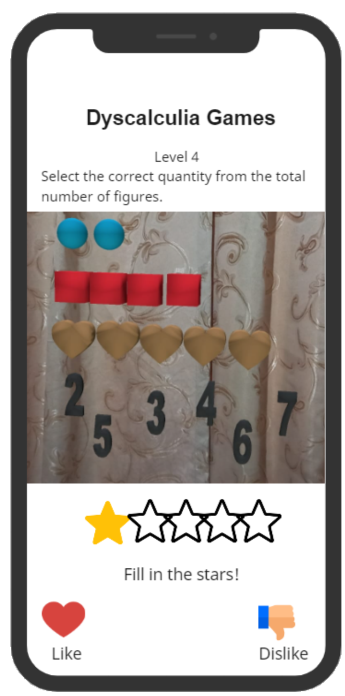

Fig. 9. Fourth Game of the Mobile Application with Augmented Reality.

E. Results of Testing

To develop this last stage of the Design Thinking methodology it is necessary to carry out a survey to validate that our prototype with augmented reality is correct for the user, in such a way that Table III identifies the five questions (Q1 and Q5) that will be sent to the users for their corresponding analysis.

TABLE III. Testing Questions

Questions for parents about the augmented reality prototype	
ID	Questions
Q1	Does the prototype meet the goal of comprehension and understanding?
Q2	Do you think that by developing this design you can improve your child's dyscalculia?
Q3	Do you think this mobile application will have a great impact on society?
Q4	Do you think that the mobile application with augmented reality should be used with the teacher or parents for better understanding or doubt?
Q5	Do you recommend the use of the augmented reality mobile application to schools and health centres for the treatment of dyscalculia?

According to the questionnaire that was carried out, 70 parents indicate their answers for each question as shown in Fig. 10, in the first question indicates that 79% say that the prototype meets the objective of comprehension and understanding and 21% say it does not. In the second question, it indicates that developing the application with augmented reality will improve the dyscalculia of their children, 83% and 17% say no. In the third question, 77% of the respondents say that the mobile application will have a great impact on society and 23% say no. In the fourth question, it indicates that 89% of the respondents say that the mobile application will have a great impact on society and 23% say no. In the fourth question, 89% indicated that the mobile application with augmented reality should be used by the teacher or guardian to check the development of their child and 11% that it should not. In the last question, parents indicated that the mobile application with augmented reality should be implemented in schools and health centres for the treatment of dyscalculia, with 84% stating this and 16% stating that it should not.

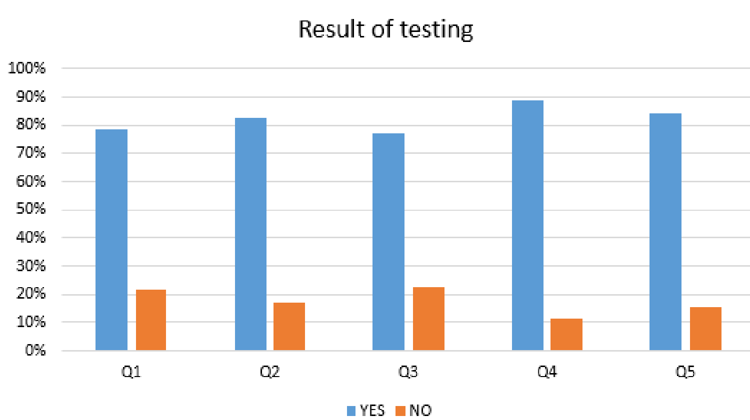

Fig. 10. Application Design Steps and Augmented Reality Modeling.

F. Expert Validation of the Prototype

To verify these validation results, which must be verified by 5 experts, the 4 criteria (Functionality, Usability, Consistency and Integration) must be taken into account, which will serve to define that the prototype has the security and acceptance by the experts.

For this it is necessary to consider that to score these criteria you must have a representative level: Low, Moderate and High. In the low level it will have as a result in the 0% to 49% shows the little interest and the low acceptance by the prototype. In the moderate level it will have the result of 50% to 79% that indicates that the prototype must obtain some improvements for its acceptance and finally the high level will have the 80% to 100%, as a result it will indicate that the prototype is considered a good project of innovation and accepted by the expert, as well as it shows in the Table IV.

TABLE IV. Level of Acceptance

Level		
Under	**Moderate**	**High**
0% - 49%	50% - 79%	80%- 100%

To find the total level of acceptance it is necessary to perform an equation, so that the criteria (Functionality, Usability, Coherence and Integration) are added up and divided by the number of criteria, so that the level of acceptance (Low, Moderate and High) is obtained.

Once the levels of acceptance are understood, the scoring of each expert should be done in such a way that each criterion is scored from 0% to 100%, and finally the total sum for each criterion and the level of acceptance of the prototype is displayed, as shown in Table V.

TABLE V. Scoring by Experts

Question about the prototype with augmented reality						
Experts	Functionality	Usability	Consistency	Integration	Total	Level
Expert 1	82%	95%	79%	80%	84%	High
Expert 2	83%	93%	86%	92%	89%	High
Expert 3	87%	85%	81%	87%	85%	High
Expert 4	89%	91%	88%	83%	88%	High
Expert 5	82%	86%	83%	91%	86%	High

In such a way Fig. 11 shows the validation by experts who have the high level of acceptance, indicating that the final prototype is a good innovation project, in detail it is shown that expert 1 shows the high level with 84%, expert 2 shows the high level with 89%, expert 3 shows the high level with 85%, expert 4 shows the high level with 88% and expert 5 shows the high level with 86%. As total average of all validations by all experts counts 86%.

G. About the Methodology

1) Advantages: The advantages of the Design Thinking methodology help us to know the needs of the users in order to solve their problems, using technology. Likewise, working in a group is effective to get to know different points of view in such a way that we reach the same objective of satisfying the client. Creativity and innovation are the main characteristics of this methodology, which involves research and analysis to come up with new ideas to contribute to society.

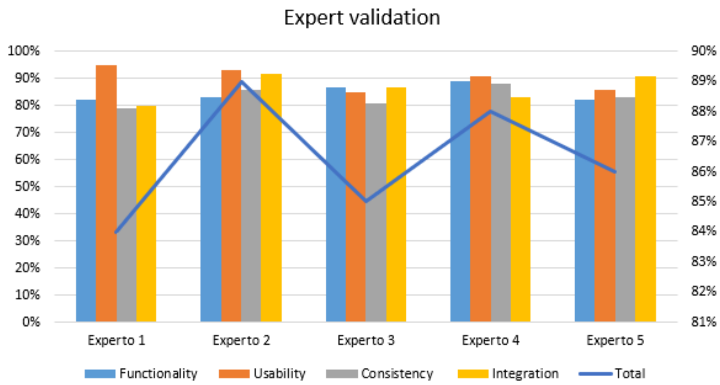

Fig. 11. Expert Validation.

2) Disadvantages: The main disadvantage of the Design Thinking methodology is the prototyping that it involves as a final solution and not in its development, so that this methodology can be grouped with other types of methodology dedicated to the development of the application in order to carry out a complete project.

3) Comparison: The Design Thinking methodology gives us the facility to use innovation and creativity to reach the needs of people, compared to other methodologies that are only responsible for the development and implementation with more complex phases [35],[36], this methodology is dedicated to the contribution to society and its ease of understanding is totally simple.

V. Discussions

In the research work that proposes to make a mobile prototype with augmented reality for dyscalculia, it turns out to be a very effective plan for the treatment of the student in such a way that there is a variety of similarities in different works that have the same objective of improving the treatment and quality in their teachings for children with problems in their understanding of mathematical operations, this coincides with the author [13],[37] which is in charge of developing augmented reality to improve children's comprehension skills in such a way that they become familiar with technology, and it is also discussed that their work makes a great contribution to society, implying that by using these technologies they can help solve different problems. On the other hand, augmented reality should be visualised by a device in such a way that the author [14], affirms the ease of having a mobile device and that when using it with augmented reality it is more effective since there are millions of users with a mobile phone in their homes, it is in this way that together the two points of view of different authors can be similar in my project giving the assurance that the development will generate a great impact on education.to know or understand the needs of users is necessary to establish multiple solutions to their problems so that the author [20], the methodology of the methodology matches our strategy, indicating that tools such as interviews and surveys are a fundamental part of the analysis with respect to the mobile application with augmented reality.

VI. Conclusions

The mobile prototype with augmented reality that is carried out in this project, proposes the improvement and treatment of dyscalculia in children in primary education, precisely a variety of problems identified by the surveys, indicating the problems that children have with their learning and the difficulty in performing their mathematical operations, for this dynamic games are made with augmented reality giving ease of understanding and comprehension. The Design Thinking methodology was a fundamental part to know the needs of the parents and the decision making by the team for the analysis of the problem, giving an infinity of ideas for the search of its solution. The prototype will not only be dedicated to education, but can also be easily integrated into health centres and clinics, in such a way that its contribution with the use of technology will be effective for the adequate treatment of children with dyscalculia. The main limitation of our project is the development of the mobile application with augmented reality, since our methodology does not focus on development, it is only used for design and prototyping.

VII. Future Work

For future work, it is suggested that this prototype with augmented reality be developed with the methodology focused on implementation or also be able to develop virtual reality technology with artificial intelligence for greater experience with the technology. In such a way that the development meets the objective of improving and treating dyscalculia in children, it is suggested that the work should be done in conjunction with specialists who have knowledge about dyscalculia for a better understanding of these learning disorders.

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References

[1] C. Luoni, M. Scorza, S. Stefanelli, B. Fagiolini, and C. Termine, "A neuropsychological profile of developmental dyscalculia: The role of comorbidity," *Journal of Learning Disabilities*, p. 00222194221102925, 2022.

[2] F. Ashraf and N. Najam, "An epidemiological study of prevalence and comorbidity of non-clinical dyslexia, dysgraphia and dyscalculia symptoms in public and private schools of pakistan," *Pakistan Journal of Medical Sciences*, vol. 36, no. 7, p. 1659, 2020.

[3] M. Barr and A. Copeland-Stewart, "Playing video games during the covid-19 pandemic and effects on players' well-being," *Games and Culture*, vol. 17, no. 1, pp. 122–139, 2022.

[4] B. V. Dorneles, "Mathematical learning and its difficulties in latin-american countries," in *International handbook of mathematical learning difficulties*. Springer, 2019, pp. 201–212.

[5] A. A. S. Martins, G. M. Paiva, C. G. R. Matosinho, E. M. Coser, P. A. d. S. Fonseca, V. G. Haase, and M. R. S. Carvalho, "Working memory and arithmetic impairments in children with fmr1 premutation and gray zone alleles," *Dementia & Neuropsychologia*, vol. 16, pp. 105–114, 2022.

[6] F. H. Santos, F. S. Ribeiro, A. L. Dias-Piovezana, C. Primi, A. Dowker, and M. von Aster, "Discerning developmental dyscalculia and neurodevelopmental models of numerical cognition in a disadvantaged educational context," *Brain Sciences*, vol. 12, no. 5, p. 653, 2022.

[7] Á. Salvatierra Melgar, W. A. Quispe-Cutipa, I. Reyes-Blácido, L. S. Rodriguez-Baca, M. F. Guevara-Duarez, and M. A. Alarcón-Diaz, "Cognitive reflections in children with adhd and proposals to promote logical thinking," 2021.

[8] J. Castro-Bedriñana, D. Chirinos-Peinado, and G. Castro-Chirinos, "Emergency remote education satisfaction during covid-19 at a public university in central andes, peru with low resources and little online teaching experience," *Educational Sciences: Theory & Practice*, vol. 22, no. 1, pp. 46–61, 2022.

[9] N. F. G. Gutiérrez, E. G. R. Arellano, J. M. Vergaray, F. d. S. T. Caceres, M. J. L. Cuadros, and E. R. Navarro, "Teaching experiences in urban and rural areas of peru in covid-19 context," *Journal of Positive School Psychology*, vol. 6, no. 2, pp. 62–70, 2022.

[10] Á. Salvatierra Melgar, W. A. Quispe-Cutipa, I. Reyes-Blácido, L. S. Rodriguez-Baca, M. F. Guevara-Duarez, and M. A. Alarcón-Diaz, "Cognitive reflections in children with adhd and proposals to promote logical thinking," 2021.

[11] K. Miundy, H. B. Zaman, A. Nordin, and K. H. Ng, "Early intervention through identification of learners with dyscalculia as initial analysis to design ar assistive learning application," in *International Visual Informatics Conference*. Springer, 2019, pp. 110–122.

[12] ——, "Screening test on dyscalculia learners to develop a suitable augmented reality (ar) assistive learning application," *Malaysian Journal of Computer Science*, pp. 92–107, 2019.

[13] R. Kariyawasam, M. Nadeeshani, T. Hamid, I. Subasinghe, and P. Ratnayake, "A gamified approach for screening and intervention of dyslexia, dysgraphia and dyscalculia," in *2019 International Conference on Advancements in Computing (ICAC)*. IEEE, 2019, pp. 156–161.

[14] T. Debnath, "Investigating the effectiveness of an augmented reality game to enhance the mathematics learning experience of dyscalculic," 2021.

[15] Z. Bhatti, N. Shabbir, M. Arshad, and M. Shaikh, "Virtual reality based android application for special children," *Journal of Information Systems and Digital Technologies*, vol. 3, no. 2, pp. 76–83, 2021.

[16] Z. Turan and G. Atila, "Augmented reality technology in science education for students with specific learning difficulties: Its effect on students' learning and views," *Research in Science & Technological Education*, vol. 39, no. 4, pp. 506–524, 2021.

[17] E. Castro-Gutierrez, "Voluminis: Mobile application for learning mathematics in geometry with augmented reality and gamification," in *Human-Computer Interaction: 6th Iberomarican Workshop, HCI-Collab 2020, Arequipa, Peru, September 16–18, 2020, Proceedings*, vol. 1334. Springer Nature, 2021, p. 295.

[18] I. Ahmad, A. J. Mohamad, F. F. Roszali, and N. Sarudin, "Dyslexiar: Augmented reality game based learning on reading, spelling and numbers for dyslexia user's," in *Computational Science and Technology*. Springer, 2021, pp. 259–269.

[19] I. J. Fitriyah, A. Setiawan, M. F. Marsuki, and E. Hamimi, "Development of augmented reality teaching materials of chemical bonding," in *AIP Conference Proceedings*, vol. 2330, no. 1. AIP Publishing LLC, 2021, p. 020043.

[20] B. Y. Yenioglu, F. Ergulec, and S. Yenioglu, "Augmented reality for learning in special education: a systematic literature review," *Interactive Learning Environments*, pp. 1–17, 2021.

[21] G. Wang, "Digital reframing: The design thinking of redesigning traditional products into innovative digital products," *Journal of Product Innovation Management*, vol. 39, no. 1, pp. 95–118, 2022.

[22] R. Kijima, M. Yang-Yoshihara, and M. S. Maekawa, "Using design thinking to cultivate the next generation of female steam thinkers," *International Journal of STEM Education*, vol. 8, no. 1, pp. 1–15, 2021.

[23] R. Parizi, M. Prestes, S. Marczak, and T. Conte, "How has design thinking being used and integrated into software development activities? a systematic mapping," *Journal of Systems and Software*, p. 111217, 2022.

[24] K. Jaskyte and J. Liedtka, "Design thinking for innovation: Practices and intermediate outcomes," *Nonprofit Management and Leadership*, vol. 32, no. 4, pp. 555–575, 2022.

[25] C. Anton, A. E. Micu, and E. Rusu, "Introducing the living lab approach in the coastal area of constanta (romania) by using design thinking," *Inventions*, vol. 7, no. 1, p. 19, 2022.

[26] C. T. A. Pham, S. Magistretti, and C. Dell'Era, "The role of design thinking in big data innovations," *Innovation*, vol. 24, no. 2, pp. 290–314, 2022.

[27] L. Vendraminelli, L. Macchion, A. Nosella, and A. Vinelli, "Design thinking: strategy for digital transformation," *Journal of Business Strategy*, 2022.

[28] J. Vrana and R. Singh, "Nde 4.0—a design thinking perspective," *Journal of nondestructive evaluation*, vol. 40, no. 1, pp. 1–24, 2021.

[29] M.-J. Tsai and C.-Y. Wang, "Assessing young students' design thinking disposition and its relationship with computer programming self-efficacy," *Journal of Educational Computing Research*, vol. 59, no. 3, pp. 410–428, 2021.

[30] H. L. Bradwell, G. E. A. Noury, K. J. Edwards, R. Winnington, S. Thill, and R. B. Jones, "Design recommendations for socially assistive robots for health and social care based on a large scale analysis of stakeholder positions: Social robot design recommendations," *Health Policy and Technology*, vol. 10, no. 3, p. 100544, 2021.

[31] E. A. Juanda and F. Khairullah, "Tinkercad application software to optimize teaching and learning process in electronics and microprocessors subject," in *6th UPI International Conference on TVET 2020 (TVET 2020)*. Atlantis Press, 2021, pp. 124–128.

[32] S. Tsolakis, T. Theofanellis, and E. Voulgari, "Introducing steam through tinkercad and arduino," in *Handbook of Research on Integrating ICTs in STEAM Education*. IGI Global, 2022, pp. 239–264.

[33] M. S. Sanadi, P. S. Satpute, and M. N. Mestri, "Simulation of drainage cleaning robotics system using solid work tinkercad software," *Asian Journal For Convergence In Technology (AJCT) ISSN-2350-1146*, vol. 7, no. 1, pp. 17–19, 2021.

[34] M. L. Amado, L. C. Ruiz, and L. Andrade-Arenas, "Prototype of an augmented reality application for cognitive improvement in children with autism using the desingscrum methodology," *Advances in Science, Technology and Engineering Systems*, vol. 6, no. 1, pp. 587–596, 2021.

[35] R. Arias-Marreros, K. Nalvarte-Dionisio, and L. Andrade-Arenas, "Design of a mobile application for the learning of people with down syndrome through interactive games," *International Journal of Advanced Computer Science and Applications*, vol. 11, 2020.

[36] F. Andrade-Chaico and L. Andrade-Arenas, "Projections on insecurity, unemployment and poverty and their consequences in lima's district san juan de lurigancho in the next 10 years," 2019.

[37] A. Carrion-Silva, C. Diaz-Nunez, and L. Andrade-Arenas, "Admission exam web application prototype for blind people at the university of sciences and humanities," *International Journal of Advanced Computer Science and Applications*, vol. 11, 2020.