Designing a Mobile Application for Children with Dyslexia in Primary Education Using Augmented Reality

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Abstract—Dyslexia is a learning disorder that hinders spelling, communication and reading comprehension, so its objective is to design a mobile application for children with dyslexia in primary education using augmented reality. In the methodology Design Thinking is used to help us solve user problems with group work and decision making to choose the best innovative proposal for its design, using mobile prototyping tools called Figma, TinkerCad is used for 3D modeling and MetaClass Studio is used to visualize augmented reality. The results show the analysis that is done to parents to find the main problems of children with dyslexia, so that the innovation team is responsible for showing the solution that is the mobile application with augmented reality so that parents feel comfortable with the proposed, the mobile prototype with augmented reality will be validated by 5 experts showing a level of acceptance of 91%, continuously will be analyzed by the usability in which tells us the user satisfaction when using the mobile application and finally will be accompanied by the process of continuous improvement for evaluation. In conclusion, it is intended to make a contribution to the educational society for the solution of dyslexia problems leading to an improvement in the child's communication.

Keywords—design thinking, dyslexia, figma, Metaclass Studio, tinkercad

1 Introduction

Dyslexia is a learning disability that affects reading comprehension and fluency, writing and spelling. There is no cure for dyslexia, there are only treatments that help improve reading skills. For a child to be diagnosed, they need to be officially aware of their written language, as phonological awareness begins to develop at the age of 4 years [1] [2]. In Malaysia, a dyslexia assessment was conducted in which 9.22% of boys and 4.66% of girls were found to have dyslexia, thus 95% of children had problems with alphabet and writing [3]. Reading difficulty is very common in dyslexia and in North America is found in 5%-11% of children with reading problems and word recognition difficulties [4].

In Latin America there is a greater problem in the treatment of these disabilities because education in children in some countries is not very efficient so that the development of their reading or comprehension skills is detected in adolescence, also consider

that dyslexia when diagnosed at an early age can improve the ability and understanding of words of the child. [5] [6]. In Brazil, the biggest problem is dyslexia, diagnosed in children aged 7 to 12 years, with problems in verbal comprehension, perceptual reasoning, working memory and processing speed. Out of 30 children, 88.3% have conversational skills and 11.7% present these problems [7].

Education in Peru is also part of the main problem for children, especially in rural areas, where teachers do not have the correct teaching and are not efficient enough for children to understand or develop their skills, so teaching materials have an influence since they are part of the educational process as children interact with them [8] [9] [9] [10]. Dyslexia or other disabilities affect their development as they become insecure when answering any question proposed by the teacher and so in some cases they isolate themselves from their environment [11] [12] [13]. Dyslexia should be treated by specialists, but in some rural areas of Peru there are no such experts to help with these disorders, so the teacher must find a way to treat the child with dyslexia [14].

The problems that were identified in the countries of the world are achieved to understand the main characteristics of dyslexia in such a way that reading comprehension and writing in children should be treated to improve education as well as treatments by specialists. In the same way that this work is proposed to solve these main problems of dyslexia nationally and globally, giving the effectiveness and interactive with digital media would be a good option to solve this problem.

The objective of the project is to develop the design of a mobile application for children with dyslexia in primary education using augmented reality, so that its operation interacts with technology that helps the child to understand in a simple way reading comprehension and word recognition, so that the child can develop their skills with different creative games that the mobile application provides. For the development of the article the following structure should be understood: in section II the bibliographic review is explained, in section III the methodology to be developed, in section IV the results of the project, in section V the discussions, in section VI the conclusions and finally in section VII the future work.

2   Literature review

The digital tools that bring in education is very important because nowadays innovation and digitalization are increasing deeply to support people in their needs, so our project aims to support in education with mobile application and augmented reality. Therefore, we are sure that the use of augmented reality for dyslexic children helps them to interact with technology, drawing their attention and facilitating specialists to de-understand their behavior with reading comprehension [15] [16]. Making a variety of innovative proposals for users with dyslexia is a great contribution, since the simulation allows those involved to give their respective opinions on the proposal until bringing it to its development, therefore the design of augmented reality in education contributes to student learning to such an extent that it fulfills its objective of including students with dyslexia and improving their participation with the use of these technologies [17] [18]. Augmented reality is one of the most effective techniques for education

and entertainment, as well as to give motivation to their students in their learning process, so this research shows that students with dyslexia use the application with augmented reality to follow the letters in such a way that they are pronounced by the students [19].

In analysis is the fundamental part since we can identify the relevant problems in those involved in such a way that a solution to the problems is sought, so in this research indicates the importance of performing this analysis in students with dyslexia, revealing the main problem that is spelling, reading comprehension, writing and the difficulty of relating to other peers for it is used tools such as surveys to parents as well as school teachers to identify the treatment between the teacher and the student with dyslexia[20]. Giving as more effective solutions today has much to do with applications, since today the person has a mobile device, tablet or computer in such a way that streamline treatments in students with dyslexia that are performed effectively therefore children are very attracted to technology [21]. There are several ways to develop augmented reality, one of them is Unity, which is used for the development of 3D modeling video games in such a way that it is a very useful tool to solve the problems of children with dyslexia [22]. Thus, this author in Malaysia indicated that the augmented reality experience provides good access to learning in such a way that the child has fun, so he uses Unity 3D which is a powerful platform that has a 3D engine for application development, so its implementation was a success as it controls stress and improves cognitive development of students with learning disabilities [23].

In terms of education is a great contribution with the help of augmented reality, in such a way that many solutions are also validated in different industries so this author indicates the importance of implementing this solution as a means of social interaction in order to provide greater customer service when shopping on the web itself using augmented reality gives greater security to the customer as they can see their product in real time [24]. As in this research a mobile application with augmented reality is implemented for tourists in order to provide a guide to reach their goal giving them satisfaction with the use of technology. For its development was used Unity 3D software with Vuforia Engine and for the mobile application Android Studio. [25]. The attention span of those involved is part of the problem, so these solutions should be implemented to improve the understanding and motivation of students in schools, academies and universities [26].

Augmented reality and mobile application is a very effective complement to solve problems in education, business and other areas, so that the literature review shows us the contribution and impact it brings to society, so it shows us the importance of using these tools. In such a way that the authors motivate us to propose this solution for primary education in Peru, also to improve reading comprehension, spelling and word recognition in children with dyslexia.

3 Methodology

In the use of the methodology, Design Thinking is used to provide innovative ideas for children with dyslexia in such a way that it is divided into 5 stages (Empathize,

Define, Ideate, Prototype and Testing), therefore, in these stages tools will be provided to develop the solution to the problem so that this section is completed.

3.1 Design thinking

Design Thinking or design thinking is better known as an innovation methodology that is dedicated to prioritize the needs of users, providing them with a variety of technological solutions to obtain a better product experience [27], its processes are easy to understand and group work is necessary to find solutions to user problems [28]. It is a methodology of great impact and highly recommended by both companies dedicated to innovation and designers to understand the problems of customers, providing them with a better expectation of their final product [29], for a better understanding of the methodology is shown in Figure 1.

Empathise. It begins with the first stage, which consists of empathizing in a way that fulfills the objective of knowing the user's needs, for which it is necessary to use techniques to identify their problems. [30]. Thus, there are tools such as surveys, interviews or techniques to analyze what users feel and think, in order to know their needs [31].

Define. It is the second stage in charge of providing solutions to the problems in such a way that it must interact with the users or work groups to lead to a solution for the development, in such a way that group work techniques must be performed, as well as knowing the main problems that the user has [32].

Ideate. Ideation is the third stage, which is very important to identify the most suitable solution for the user, so the main problems must be taken into account and understood. The work should be done in a group and for this purpose techniques are used to discuss what would be the best option for the end user [33].

Prototype. Prototyping is the fourth stage to capture the solution at a glance, so it should be shown in the form of a mock-up or design that visualizes the solution required by the user [34]. To achieve a good prototype, the team should use specific design tools or sketches to show the solution [35].

Testing. Testing is the last stage of the methodology, which must meet the objective of finding user satisfaction with the prototype, in this way the user will be responsible for indicating that the product is stable for development, otherwise it helps us to improve the product with new updates in order to be questioned again by the end user [36]. For this methodology it is necessary that the work team contacts the users through surveys or interviews for their respective analysis [37].
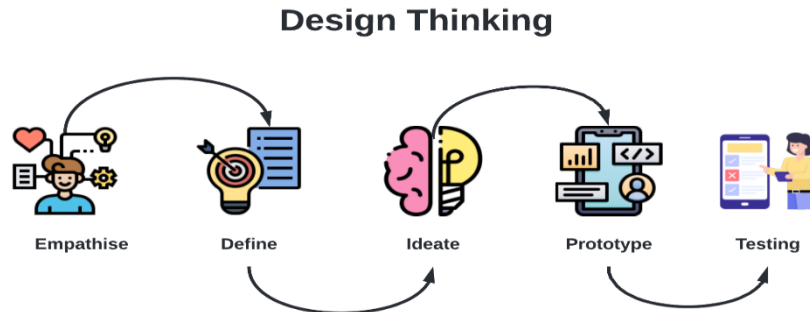
Design Thinking

Fig. 1. Methodology design thinking

3.2 Tools for the design of mobile application with augmented reality

In this section we will show the tools for the design of the mobile application with augmented reality, thus showing the relationship between both technologies for the fulfillment of the objective of our project as shown in Figure 2.

Figma. It is a tool for web or mobile prototyping, its functionality is very intuitive to show the client in such a way that accepts group work and perform the design in real time in such a way that it is hosted in the cloud, also has plugins to appreciate the visualization of the design, it can be used from the browser or downloading the application on the computer. [38].

Tinkercad. It is a free application dedicated to perform designs or 3D modeling in such a way that it is very useful for users with no design experience, allowing them to perform from basic to more complex models [39]. Therefore, it has a wide variety of options among which are circuit simulation or programming in Arduino, its ease of access to the application is very simple since it can be entered from the browser from the computer, laptop or cell phone [40][41].

MetaClass Studio. It is a free mobile application that visualizes models with augmented reality, in such a way that its usefulness is basic since any user can interact with the application to improve their expectations and relate to technology, this application allows us to introduce our designs in such a way that facilitates the visualization of our projects with augmented reality [42].
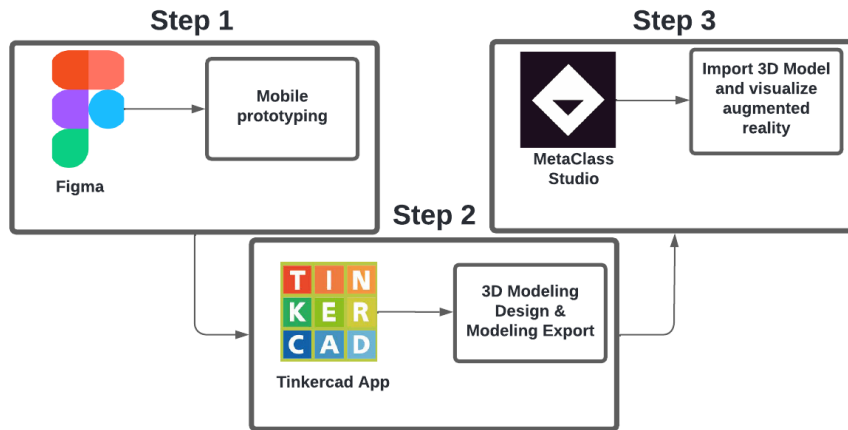
Fig. 2. Structure of mobile design with augmented reality [43]

4 Results

This section will present the results of the stages of the Design Thinking methodology, showing the solution to the problems of users in such a way that design tools will be used to make the mobile prototype with augmented reality, giving way to a validation by experts to ensure that the mobile prototype with augmented reality is a good contribution to dyslexia, also applies the usability analysis to know the interaction of the child with the mobile application, accompanied by the process of continuous improvement to evaluate the previous work with the applied and at the end will have its advantages, disadvantages and comparisons that has the methodology.

4.1 Results of empathise phase

To obtain the results of the first stage of the methodology, surveys will be used to learn about users' problems, so that 6 questions (Q1 to Q6) will be asked, as shown in Table 1.

Table 1. Questions

ID	Questions
Q1	What grade of primary school is the child in?
Q2	Gender?
Q3	In which district of Lima is the child located
Q4	Does the child have reading problems?
Q5	Is the child unable to socialize with others due to lack of communication?
Q6	Does the child have spelling problems?

4.2 Results of the define phase

Regarding the results of the second stage, to analyze the questions answered by parents (R1 to R6), Table 2 shows that 80 parents completed the survey.

Table 2. Survey response

ID	Answers
R1	First Grade Primary 38%, Second Grade Primary 17%, Third Grade Primary 13%, Fourth Grade Primary 11%, Fifth Grade Primary 12%, Sixth Grade Primary 9%
R2	Male 75% Female 25%
R3	Los Olivos 15%, San Martín de Porres 17%, Carabayllo 20%, Lima 10%, Independencia 17%, Comas 21%
R4	Yes 72%, No 28%
R5	Yes 86%, No 14%
R6	Yes 77%, No 23%

R1. The first response indicates that respondents had the greatest impact in the first grade of primary school with 38%, in the second grade of primary school with 17%, in the third grade of primary school with 11%, in the fifth grade of primary school with 12%, and in the last grade of sixth grade of primary school with 9%.

R2. In the second response, indicate the sex of the children evaluated so that 75% are boys and 25% are girls.

R3. The third response indicates the district in Lima where the child is located: in Los Olivos 15%, in San Martin de Porres 17%, in Carabayllo 20%, in Lima 10%, in Independencia 17% and in Comas 21%.

R4. The fourth response discusses the child's reading problems, with 72% of the 80 respondents answering Yes, and 28% No.

R5. In the fifth response, communication problems with other children are analyzed, so that 86% of the 80 respondents answered yes and 14% answered no.

R6. The sixth response refers to the child's spelling problems, with 77% affirmative responses and 23% negative responses. The second response refers to the child's spelling problems.

4.3 Results of ideate phase

In the ideation results, the ideas are made according to the problems identified in the second phase, so that the innovation team is in charge of deciding which of the ideas has the greatest impact on solving the problem, as shown in Figure 3, where it can be seen that the idea with the greatest impact is augmented reality.
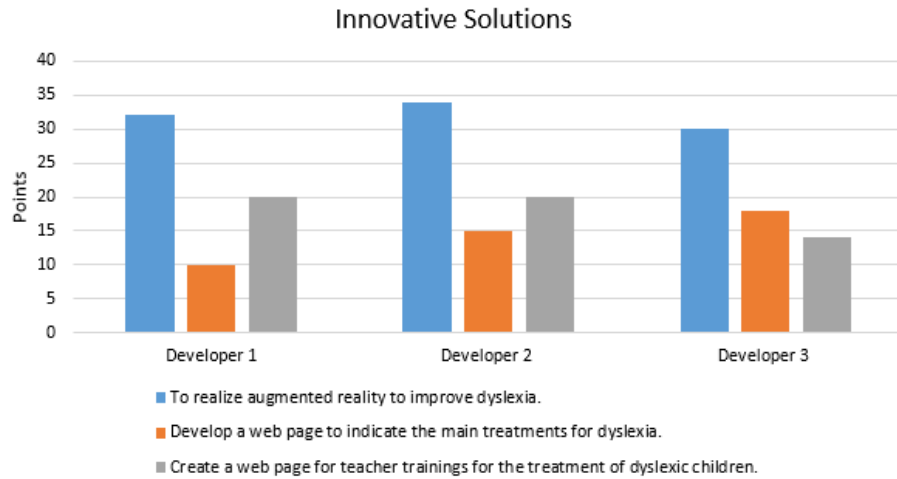
Fig. 3. Result of ideate

4.4 Results of prototyping phase

In the results for the mobile design prototype with augmented reality, the tools mentioned in Figure 2 are used, so the usefulness of the application will be explained since it is the solution provided to the user, so it starts with the entrance to the application called Educadylexia APP where the user can start the application by pressing the Start button as shown in Figure 4.
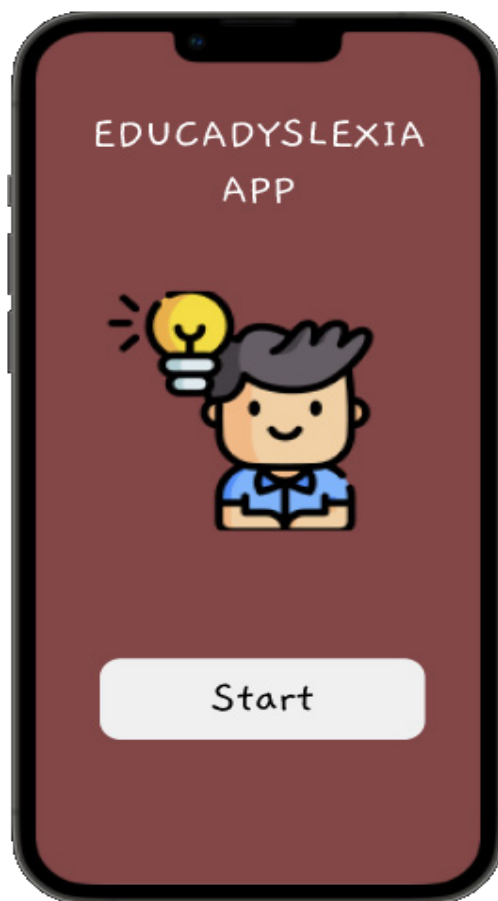
Fig. 4. Start of the mobile application [44]

Figure 5 shows the registration process that starts with the login to the application where the user will enter his account with his email and password, otherwise if the user does not have a login account, he should click on the Register button for the user to complete the form requested by the mobile application or if he has forgotten his password, he should click on the password recovery button.

Fig. 5. Registration process

Figure 6 shows a model of how to recover the user's password, so that the user must enter his registered e-mail address, and can also reset his password.
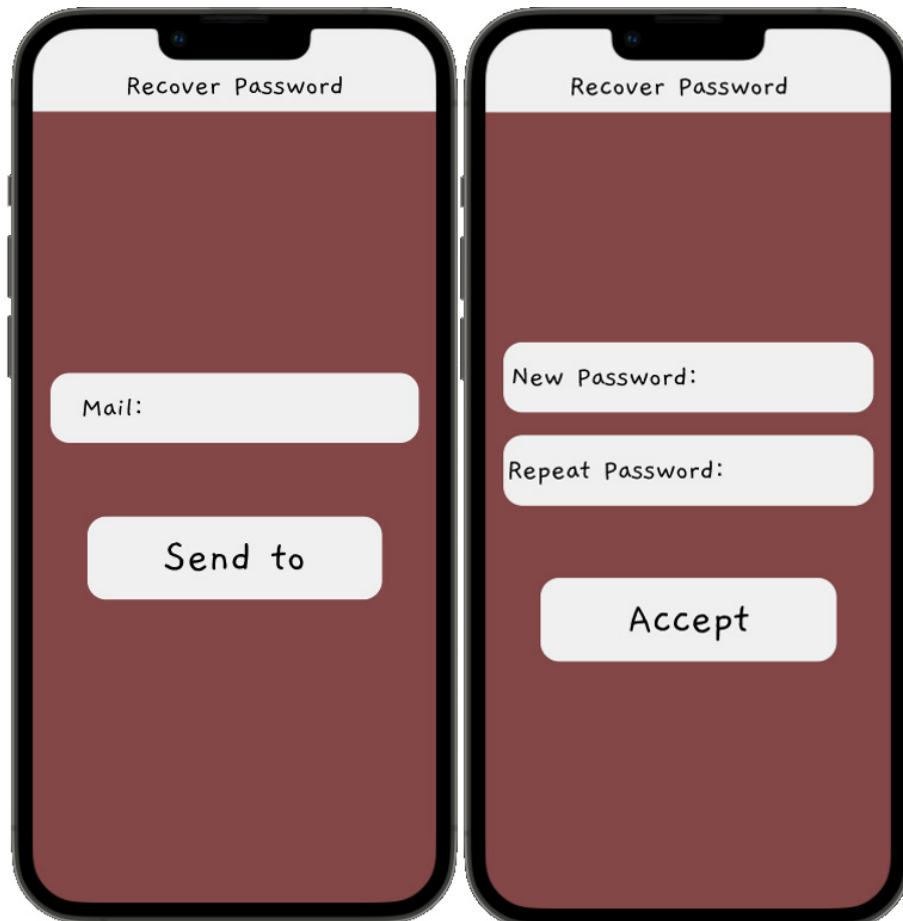
Fig. 6. Password recovery

Figure 7 shows that the user has to choose his grade level to select the first level to start the game for dyslexia treatment.
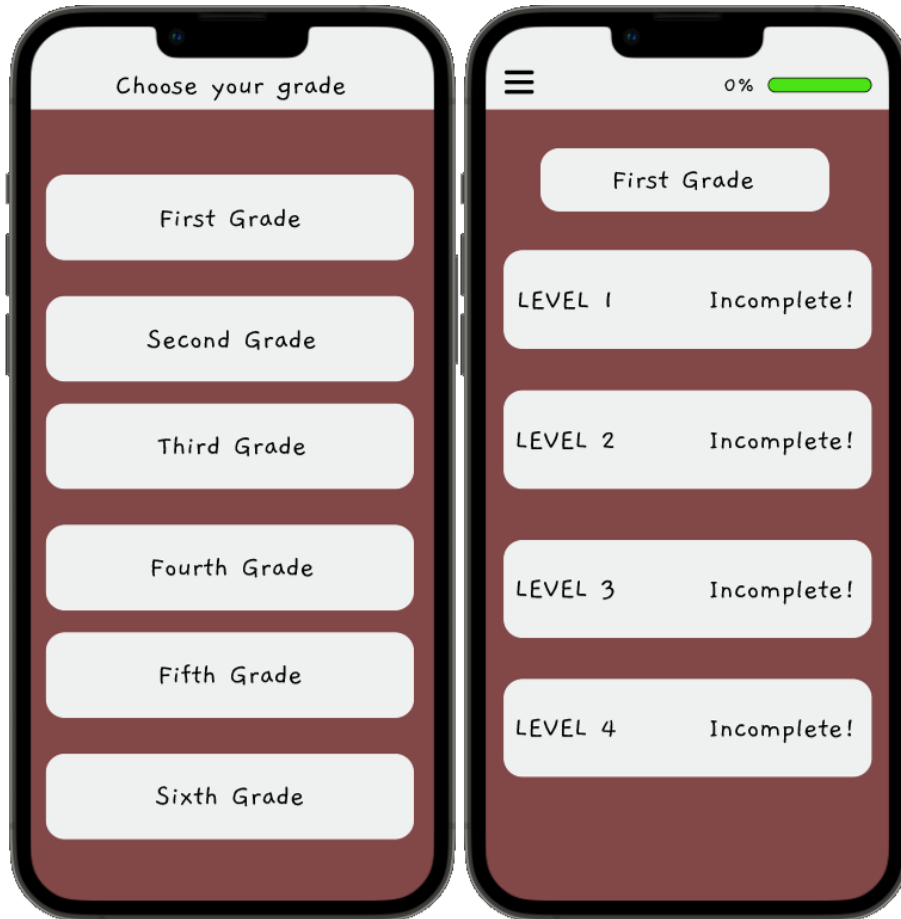
Fig. 7. Choose grade and level of play

In the first level of the augmented reality game for dyslexia, as shown in Figure 8, the child has to choose the vowels and fill in the empty boxes.
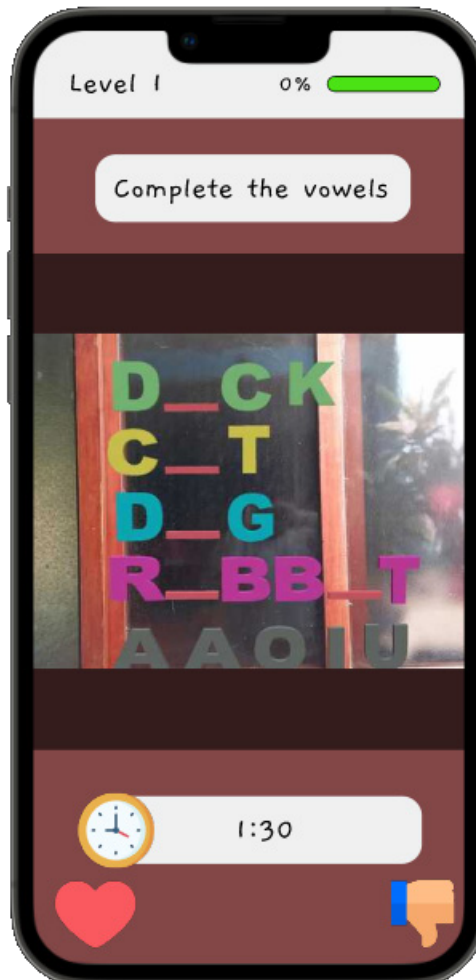
Fig. 8. First augmented reality mobile app game for dyslexia [45]

In the second level of the augmented reality game for dyslexia, as shown in Figure 9, the child has to form the words according to the image.
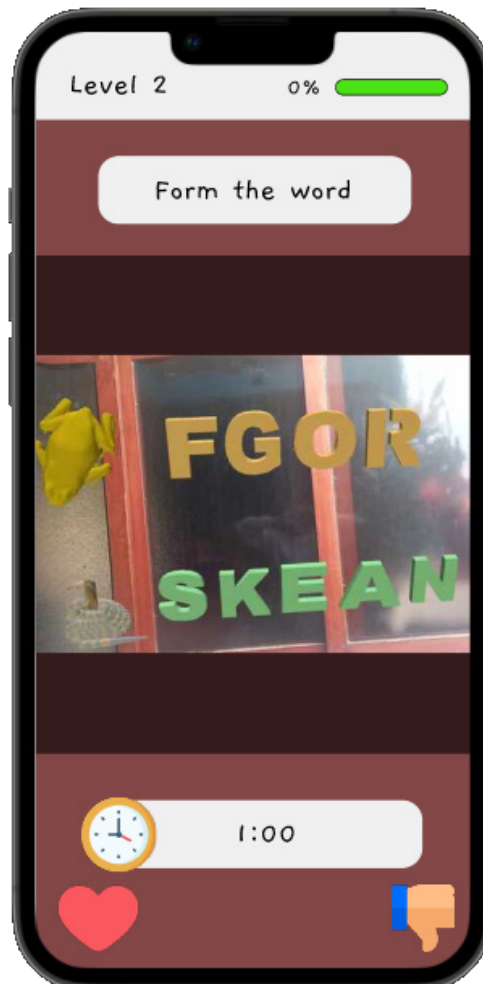
Fig. 9. Second game of augmented reality mobile application for dyslexia

In the third level of the augmented reality game for dyslexia, as shown in Figure 10, the child has to complete the word.

Fig. 10. Third game of augmented reality mobile application for dyslexia

In the fourth level of the augmented reality game for dyslexia, as shown in Figure 11, the child has to choose the correct word, so these games mentioned above should be supported by the teacher, dyslexia specialist or parents to guide the child.

Fig. 11. Fourth game of augmented reality mobile application for dyslexia

4.5 Results of testing phase

For the last stage of the Design Thinking methodology, a parent survey should be conducted to validate the prototype with augmented reality, so that the user answers the questions asked from (Q1 to Q5) as shown in Table 3.

Table 3. Testing questions

ID	Answers
Q1	Believes that the application with augmented reality will be able to improve the spelling of the child with dyslexia?
Q2	Do you think the augmented reality application will improve the word recognition of the child with dyslexia?
Q3	Do you think the augmented reality application will be able to improve communication for the child with dyslexia?
Q4	Do you think the application with augmented reality can be used to improve education at the primary level?
Q5	Should this solution be implemented in hospitals or clinics that have treatments for early stimulation?

According to the 80 respondents about the mobile prototype with augmented reality, the answers to their questions are shown for their respective analysis, so that in the first question indicates that 80% will improve their spelling and 20% will not, in the second question indicates that 83% will be able to improve word recognition and 17% will not, in the third question it indicates that 77% of children with dyslexia will be able to improve their communication and 23% will not, in the fourth question it indicates that 82% agree that the prototype can be a great contribution to primary education and 18% do not, in the fifth question it indicates that 97% suggest implementing this solution in hospitals and clinics dedicated to early stimulation and 3% do not, these results are shown in Figure 12.
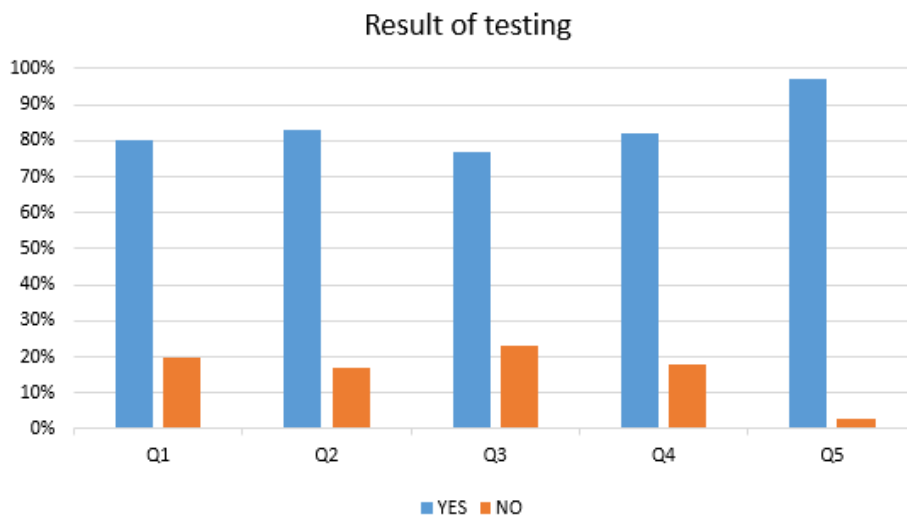

Fig. 12. Result of the testing stage

4.6   Expert validation of the prototype

To perform the validation of the prototype by experts, the 4 criteria (Functionality, Usability, Consistency and Integration) must be considered to validate the acceptance by the five experts. In this way, the level of all the criteria must be known for its score. The low level will have a score from 0% to 49% where it will be detailed that the mobile prototype with augmented reality has little impact for the user. The moderate level will have a score of 50% to 79% where it will detail that the prototype can be optimized for acceptance. The high level will have a score between 80% to 100% where it will detail that the mobile prototype with augmented reality is a good contribution to society and is suitable for implementation. To obtain the total level of acceptance, the scores of the 4 acceptance criteria are added together and divided by the number of criteria, thus obtaining the level of acceptance (Low, Moderate and High), these levels are shown in Table 4.

Table 4. Level of acceptance

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

Table 5 shows the scores for each acceptance criterion, with the five experts responding to each criterion from 0% to 100%.

Table 5. Scoring by experts

Experts	Functionality	Usability	Consistency	Integration	Total	Level
Expert 1	90%	100%	98%	88%	94%	High
Expert 2	89%	95%	95%	93%	93%	High
Expert 3	92%	89%	96%	87%	91%	High
Expert 4	87%	89%	86%	83%	86%	High
Expert 5	95%	90%	87%	91%	91%	High

Figure 13 shows the validation approval by the experts, the first expert indicates a total of 94%, the second expert indicates a total of 93%, the third expert indicates a total of 91%, the fourth expert indicates a total of 86%, the fifth expert indicates a total of 91%, with an average total of 91% indicating the high level of approval, so mobile design with augmented reality is the suitable innovation solution for dyslexia treatment.
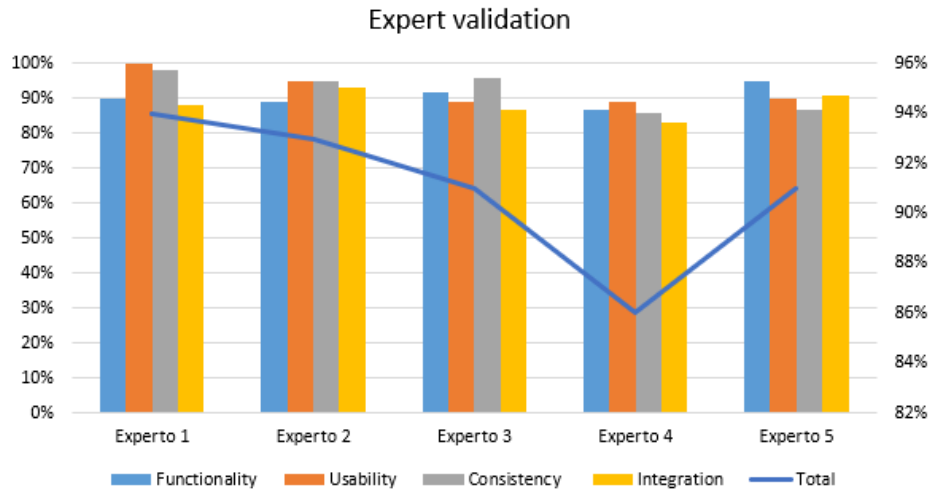
Fig. 13. Expert validation

4.7 Usability analysis

Table 6 shows the ease of learning that children have when interacting with the application, as well as the effectiveness of their dyslexic treatment and the satisfaction of the dyslexic child when using the mobile application, this analysis is also accompanied by the teachers and parents in charge of supervising this treatment.

Table 6. User ratings

Experts	Ease of learning	Efficiency	Satisfaction	Total	Level
Dyslexic Children	98%	99%	97%	98%	High
Parents	95%	96%	98%	96%	High
Teachers	95%	97%	99%	97%	High

Figure 14 shows the usability analysis such that children have a high acceptance level of 98%, parents have a high acceptance level of 96% and teachers have a high acceptance level of 97%, concluding that the mobile application is acceptable to the user.
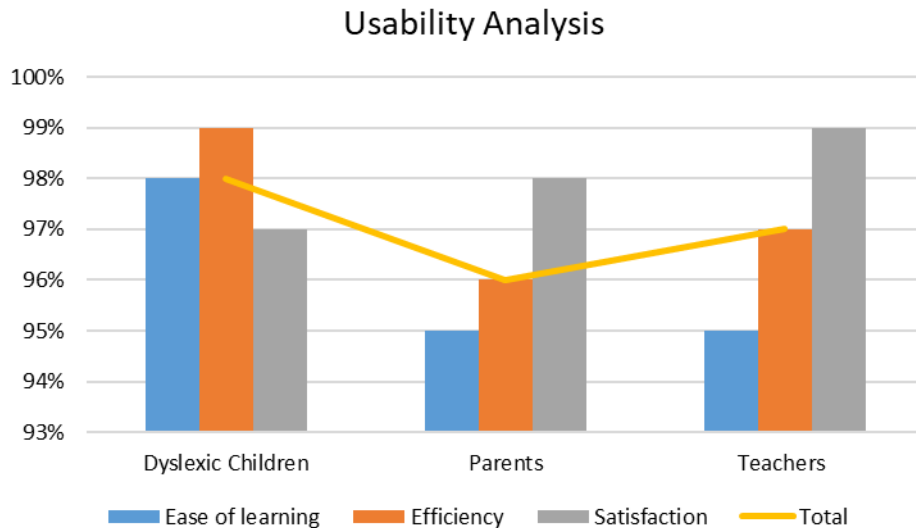
Fig. 14. Usability analysis

4.8 Continuous improvement process

For this it is necessary to understand how this procedure of the mobile application for dyslexia is evaluated to understand the process of continuous improvement, therefore it is necessary to analyze how it worked previously for this treatment and what improvements we get using this mobile application for children with dyslexia, as shown in Table 7.

Table 7. Continuous improvement process

Before	After
Child with more stress.	Decreases the level of stress by learning a new way of learning.
Child with more mistakes in solving their treatments.	Comprehension in their treatments ending successfully.
Child confused in naming words.	Improved word naming with the use of the mobile application.
Child isolated from peers by withdrawing from subjects.	Catching up with children in classroom.
Child is easily distracted.	Has increased attention span by using technology and solving their mobile app treatments.

4.9 About the methodology

Advantages. The advantage of the Design Thinking methodology is that it responds to user needs in such a way that it seeks innovative solutions in the short term. This methodology is based on group work, so that it uses various techniques to analyze the user and seek solutions to their problems.

Disadvantages. The disadvantage of this Design Thinking methodology is that it does not cover the development of the solution, it only focuses on the design of the idea or solution.

Comparison. Design Thinking is dedicated to the search for solutions and innovation, compared to other methodologies such as Scrum that is responsible for product development, so it uses techniques for teamwork, so it involves the development of software adaptable to changes, presenting the functional product. On the other hand the waterfall methodology that is also used for the implementation of the product, the only difference is that it is not adaptable to changes and any incident can be risky for the project and finally the RUP methodology that is responsible for analyzing, implementing and documenting the system, it can also be assured that the mentioned methodologies can complement each other.

5 Discussions

In our project of mobile design with augmented reality for dyslexia is very innovative for the treatment of children in such a way that there are several times of developments or designs that are assimilated to our objective in such a way that improves education or other learning disorders in such a way that agrees with the author [24] , which is responsible for developing augmented reality for the cognitive development of children with learning disabilities since technology causes curiosity towards them in such a way that improves their concentration. That is why by making this innovation it would be clear that the use of technology such as augmented reality can be a great advantage for education, agreeing with the author 10 in such a way that suggests using augmented reality for dyslexia as it is very useful to improve their reading comprehension. In such a way that the analysis for our project is a fundamental part to know the users and give a solution, according to the author [15] the mobile application attracts the attention of the child with dyslexia since it is a training for them, in such a way that in our project is dedicated to the mobile application with augmented reality, also that the author of the project is dedicated to the mobile application with augmented reality. The mobile application draws the attention of the child with dyslexia as it is a training for them, so that in our project is dedicated to the mobile application with augmented reality, as well as that the author [17] indicates the usefulness of the mobile application, because nowadays people have a mobile device, so it is very useful for children to learn or improve dyslexia at home.

6 Conclusions

This mobile design project with augmented reality for dyslexia proposes to improve reading comprehension and spelling so that the child is able to communicate without the difficulty of speaking. In such a way that its solution is oriented to make cognitive games for the child, for this it is complemented with the use of the Design Thinking methodology since it is the main part for the solution of the user's problems giving him a variety of innovative proposals, in such a way that at the end the mobile design with

augmented reality is provided. The main limitation is not to present the developed product since the methodology used is focused on the design of mobile or web prototypes.

In future works it is suggested that the mobile design with augmented reality be developed with agile methodology, it can also be complemented with artificial intelligence since it generates a greater impact on society, these works are focused on improving the treatment of dyslexia, so it should be implemented in hospitals or clinics and for the use of the application should be complemented with a specialist in dyslexia for the orientation of the child.

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