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# Augmented reality for anatomy course for children with autism

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**ABSTRACT**

Autism spectrum disorder (ASD) that mainly affects social interaction and effective communication, showing problems in their learning, reflected in the lack of attention in schools, such as in anatomy classes. The main objective of the project is to develop a mobile application for children with autism to improve their learning in Anatomy and social interaction through augmented reality (AR). The methodology to be used is ADDIE which is in charge of analyzing the experience of the work team to find the ease of software development, proposing the efficient development with continuous improvement according to the evaluation to the specialists. The results show the evaluation of the specialists on the mobile application with AR where they will indicate their satisfaction with the application. In conclusion, it will be shown a mobile application with AR that offers a technological and eye-catching novelty for users in order to improve the educational development of children with autism spectrum disorder.



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## 1. INTRODUCTION

Autism spectrum disorder (ASD) primarily affects social interaction and effective communication and is characterized by repetitive behaviors and strong individual interests. Individuals with autism often have difficulty interpreting subtle social cues and may have trouble initiating or maintaining conversations, and often excel in specific areas, such as memorizing information or focusing on topics of interest. It is essential to understand that Asperger syndrome is part of an autistic spectrum, with a diversity of abilities and challenges among those affected [1], [2]. People diagnosed with autism face various challenges in their daily routine, their social interaction is hampered by difficulty in understanding nonverbal cues and implicit rules. They also experience difficulties in communication, both in initiating and maintaining conversations and in interpreting humorous tones and expressions. In addition, they tend to develop repetitive patterns of behavior and show intense interests, which complicates their adaptation to changes in the environment [3], [4]. During the COVID-19 pandemic, people with Asperger Syndrome have faced new challenges, such as changes in routine and adaptation to technology, which can increase stress, especially for those who were already in therapy before the pandemic. Globally, ASD are more common in boys than girls, with symptoms detectable at an early age and may include delays in language and social development; 11% of people with ASD may not fully develop their skills and require hospitalization before adulthood [5], [6].

Children with autism face a number of challenges in anatomy classes; their limited ability to socialize can make group collaboration and joint activities difficult. In addition, their heightened sensory sensitivity can make certain aspects of the class, such as the use of anatomical models, overwhelming. Even if they are interested in anatomy, their excessive attention to specific details may hinder overall comprehension. Comprehension of abstract concepts can also be challenging without adequate visual

support, just as the lack of structure can create stress, as they prefer routine and may need additional support to adapt to changes in classroom dynamics [7], [8]. The integration of children with autism into the Latin American educational system faces particular challenges; despite some advances in awareness and resources, significant barriers remain. Limited teacher training in specialized education and lack of adequate resources to address the individual needs of these children are common obstacles, and stigmatization and lack of understanding of Asperger Syndrome in certain communities can hinder their effective integration into schools [9], [10].

The traditional educational system can pose challenges for children with Asperger Syndrome due to their specific needs, although some may adapt well as well as many need additional accommodations and supports. Characteristics of the syndrome, such as difficulties with social interaction and sensory sensitivity, may influence their experience in the classroom [11], [12]. Educational inclusion in some Peruvian schools faces significant challenges due to the lack of formality and lack of specialized teachers. Discrimination against people with autism can negatively affect their self-esteem. Adults with ASD often face difficulties in finding employment due to a lack of understanding of their abilities, which limits their employment opportunities. Emphasize the importance of early diagnosis as a fundamental tool to prepare people with ASD for a future and independent life [13], [14].

The relevance of this introduction lies in highlighting the main challenges we face by not having the necessary resources to access autism specialists, which is especially evident in Latin America. In this context, the objective of the article is to develop a mobile application aimed at children with autism, in order to improve their learning in anatomy and social interaction through the use of augmented reality (AR). This approach seeks to optimize educational processes and promote school inclusion, as well as to offer effective and interactive solutions in the Peruvian community using technology as a key tool.

## 2. LITERATURE REVIEW

The idea of proposing mobile applications has improved the industries and educational systems bringing new developments such as AR, virtual reality and artificial intelligence being the technological revelation of the moment. This author talks about a solution related to dyslexia, a learning disability that affects reading, word decoding, comprehension, memory, writing, spelling, and speech shows as a proposed solution a mobile application designed to help dyslexic users who face reading and writing difficulties in real world situations. The application has the ability to display text, such as alphabets and numbers, in the dyslexic user's surrounding environment and read it aloud. In addition, the need to use a machine learning approach to increase the effectiveness of education for children with dyslexia is mentioned. The application is presented as a tool that could contribute to overcoming the difficulties faced by people with dyslexia by providing reading and writing support in their daily lives [15]. This author discusses a solution related to mobile learning (ML) in education. The widespread use of mobile technologies and portable devices is mentioned, as well as their popularity among young people. The proposed solution is an educational application for Android designed to help Greek high school students with learning difficulties in mathematics [16]. Similarly, this author discusses the design and development of a mobile application intended to provide assistance to people with dyscalculia, a disorder that makes it difficult to learn mathematical concepts. The aim of the application is to address the specific difficulties associated with dyscalculia, such as understanding mathematical concepts, performing arithmetic operations, and memorizing mathematical terms [17].

This author talks about AR and how children interact with the application is why he created the app "ARLexic" is a serious game based on AR developed to train children with dyslexia and dysgraphia, this research is treated to children with 7 to 14 years, along with their teachers, to evaluate the performance of the game. The results of the study show that it is a game that is entertaining and easy to use for children, and that AR encourages greater interaction and participation on the part of children [18]. The author of this study indicates that AR supports motivation and creativity for elementary school students, specifically in the context of geometry learning. The impact of AR on the motivation and creativity of elementary school students is investigated. An inquiry-based design process is used, where students in the experimental group use mobile applications to access virtual AR manipulatives, while students in the control group use physical manipulatives [19]. This author conducts a research project that focuses on the development of a mobile application for the visualization of the solar system using AR technology on the Android platform. The application aims to facilitate effective training in the study of subjects related to the astronomical cycle in elementary school. AR provides a more immersive visualization experience, converting 2D images into 3D representations and allowing to "bring to life" images of the solar system [20].

This literature review highlights the significant relevance of AR in various disease management applications, presenting proposed solutions similar to our thematic focus. Several authors have addressed the utility of AR in healthcare, offering valuable perspectives that support our central objective in this article. The initial motivation lies in the need to address and fulfill the main objective of the study, which focuses on

the application of an innovative solution. Through this review, the convergence of ideas among different experts is highlighted, consolidating the importance of AR as an integral tool in solving medical challenges. The variety of approaches and applications reviewed reinforces the idea that AR can offer versatile and effective solutions to improve the care and treatment of various diseases.

## 3. METHOD

The methodology will explain an exhaustive description of the tools selected for the creation of AR experiences. This analysis will include not only the functionality and use of the tools, but also their strategic integration in the development process. In addition, a detailed overview of the content of the methodology will be provided, covering each phase of the process and highlighting its importance in the successful implementation of AR. This comprehensive approach will ensure a complete and accurate understanding of the resources and steps required to effectively carry out AR projects.

### 3.1. Technological tools

#### 3.1.1. C-Sharp

C-Sharp, also known as C#, is a programming language created by Microsoft, widely used in the construction of desktop, web and game applications, especially recognized for its integration with Unity in video game development. Based on object-oriented programming, it employs object and class concepts for efficient code organization. Its versatility extends beyond Windows thanks to .NET Core, allowing development on systems such as Windows, Linux, and macOS. This cross-platform capability makes it attractive to developers looking to create robust software that is compatible with a variety of operating systems [21].

#### 3.1.2. Unity

Unity is a versatile engine for video games and applications in 2D, 3D, virtual and AR, as well as for simulations in various fields such as architecture, medicine and education. It stands out for its intuitive user interface, accessible to developers of all levels. With cross-platform support, it allows development on systems such as Windows, macOS, iOS, Android, Xbox, and PlayStation. Its ease of use makes it popular among novice and expert developers alike, making it a powerful tool for creating interactive content [22].

#### 3.1.3. Vuforia

Vuforia stands out as the leading platform for the development of AR experiences, enabling the visualization of 3D graphics on mobile devices and tablets. Its ability to identify and track objects in the real environment facilitates the creation of interactive applications that seamlessly integrate with physical elements. The tool is versatile, recognizing objects and QR codes, which expands the possibilities for developers. By superimposing digital information on the real environment, Vuforia becomes essential for immersive experiences in sectors such as education and entertainment. It is cross-platform, compatible with iOS, Android, Unity and others, simplifying AR development for various platforms [23].

### 3.2. Addie

The ADDIE methodology is a systematic approach to the design and development of learning programs, with five main phases. The process begins with analysis, where needs are identified and the context is understood. Then, in the design phase, instruction is planned by establishing objectives and teaching methods. Development involves the creation of content and learning materials. Subsequently, Implementation is responsible for delivering the program to learners. Finally, evaluation assesses the effectiveness of the program and guides future improvements. ADDIE offers a flexible framework that allows for adjustments based on feedback, ensuring effective instruction [24], [25], Figure 1 shows the graph of the methodology.

#### 3.2.1. Analysis

The analysis helps to clearly define the problems being addressed and to establish specific and measurable goals for instruction. It also identifies the skills and prior knowledge of the developers, which is critical to designing an effective learning program tailored to the needs of the target audience [26]. This part details the resources required to carry out the project, as presented in Table 1. This stage reveals the individual experience of each developer, which allows identifying the tools and languages with the highest scores. In this way, the most appropriate technologies are chosen for the development of the mobile application with AR, based on the experience and skills of the team members. The evaluation of these competencies ensures an efficient allocation of tasks and resources, thus optimizing the development process.

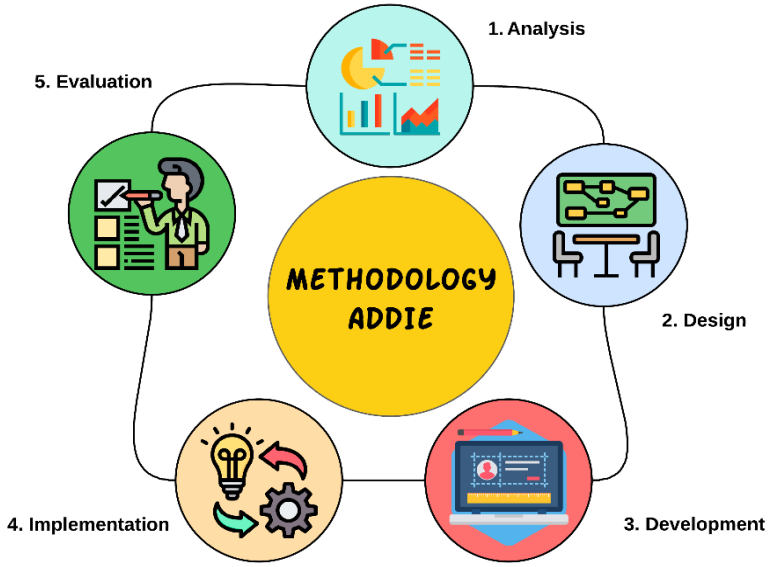



Figure 1. Methodology addie

Table 1. Results of the analysis

| Validation | Developer 1 | Developer 2 | Developer 3 | Developer 4 | Developer 5 |
|---|---|---|---|---|---|
| Figma | 100% | 100% | 100% | 100% | 100% |
| Vuforia | 95% | 95% | 98% | 98% | 98% |
| Unity | 90% | 92% | 93% | 92% | 91% |
| ARCrowd | 30% | 25% | 25% | 50% | 70% |
| Augmented class | 100% | 50% | 56% | 43% | 59% |
| Roar | 25% | 25% | 25% | 25% | 25% |
| Andorid Studio | 95% | 87% | 87% | 88% | 87% |
| Flutter | 90% | 40% | 50% | 70% | 50% |
| C# | 95% | 97% | 98% | 90% | 100% |
| Java | 85% | 80% | 50% | 50% | 50% |
| C++ | 50% | 50% | 100% | 50% | 20% |
| Python | 20% | 25% | 15% | 30% | 70% |
| Kotlin | 50% | 50% | 90% | 50% | 70% |
| Windowns | 100% | 100% | 100% | 100% | 100% |
| Linux | 50% | 70% | 60% | 60% | 60% |
| maCOS | 50% | 50% | 50% | 50% | 50% |
| Unix | 20% | 20% | 10% | 10% | 5% |

### 3.2.2. Design

The Design phase serves to plan and structure the instruction in detail, during this stage, the specific learning objectives are established, the most appropriate teaching methods are identified and the learning activities are designed. In addition, it is determined how the information will be organized and presented to facilitate the learning process [27]. The design process to achieve the objective involves the creation of a mobile application with AR, as shown in Figure 2. In this app, the Vuforia tracker is essential to process and recognize objects, facilitating the effective implementation of AR. The collaboration between Vuforia and Unity improves the graphical quality of 3D presentations. The interaction between the two tools offers a more immersive AR experience. This combined approach ensures optimal performance, highlighting the importance of integrating specialized tools to achieve goals and provide an exceptional user experience.

### 3.2.3. Development

This is the third stage develops the creation of the project using the planned resources to meet the objective and establish best practices, working between designers and developers to build the project [28], [29]. In this phase, we focus on the development of the mobile application with AR technology. Figure 3 presents the first stage of this development, where the user is required to interact by clicking on the screen to log in, as illustrated in Figure 3(a). Subsequently, the authentication process progresses, reaching its culmination when the user logs in with his previously registered account, as exhibited in Figure 3(b). This intuitive and user-friendly approach ensures a smooth and secure entry to the application, significantly improving the overall user experience.

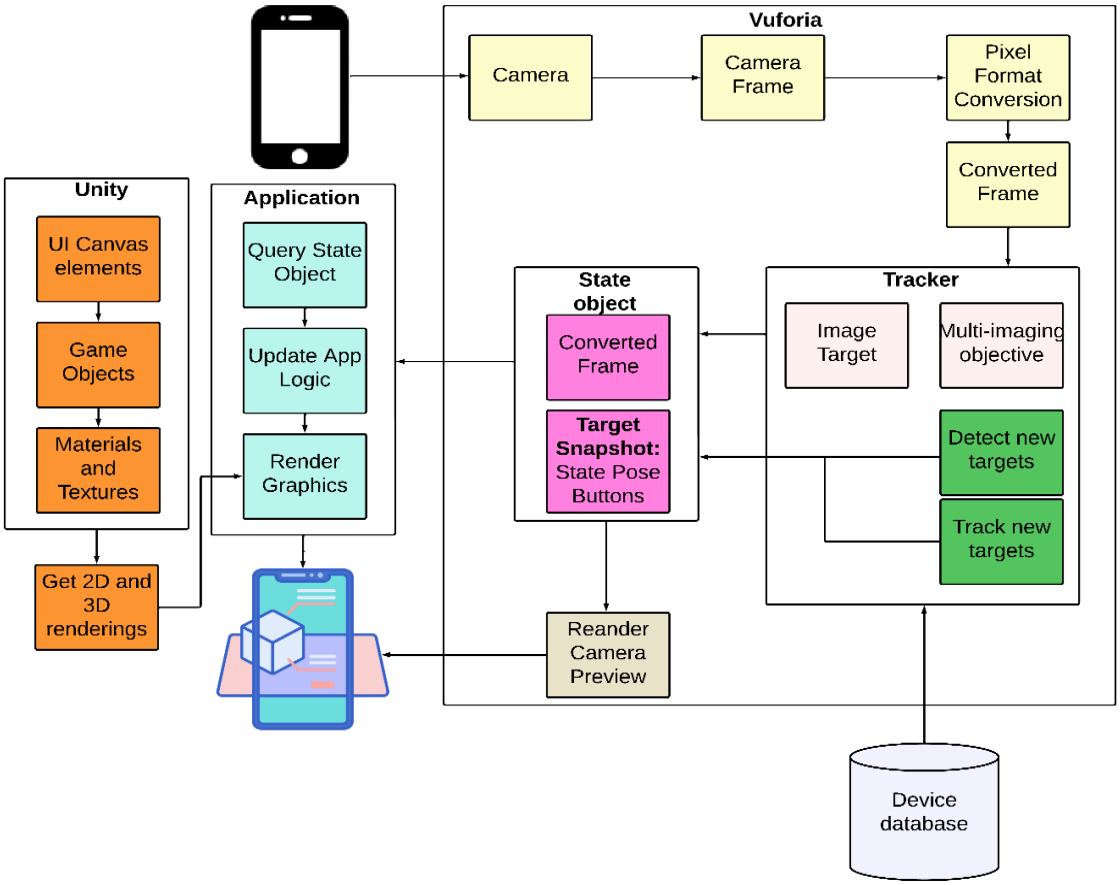



Figure 2. Design of the AR development process


(a) (b)

Figure 3. APP home (a) start application and (b) login

In this phase of the process, our attention is focused on the development of the functionality represented by Figure 4. This stage is essential for new users to successfully register on the platform. Figure 4

illustrates in detail the proper procedure that a new user must follow when entering the required data, such as name, password, email, country, cell phone number, and age. This registration process is designed to be clear, accessible and provide a smooth experience, ensuring that users can provide the necessary information efficiently and successfully.

This graphical representation, shown in the Figure 5, highlights the simplicity of the process for resetting the password in case a user has forgotten it. This mechanism has been carefully designed to avoid any inconvenience related to the loss of crucial information. In the first instance, identified as Figure 5(a), the user simply enters the e-mail address associated with his or her account. Subsequently, in Figure 5(b), the user is prompted to enter the new password they wish to set. This efficient and secure approach ensures a smooth experience, allowing users to regain access to their account quickly and reliably.

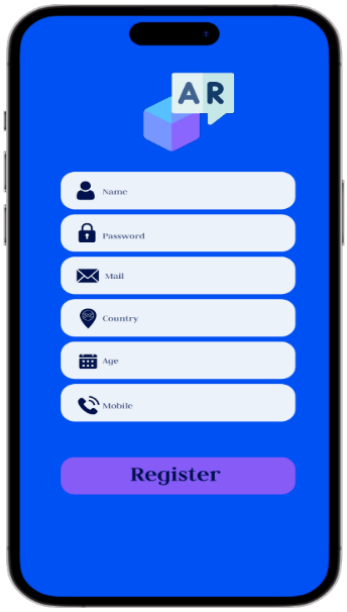
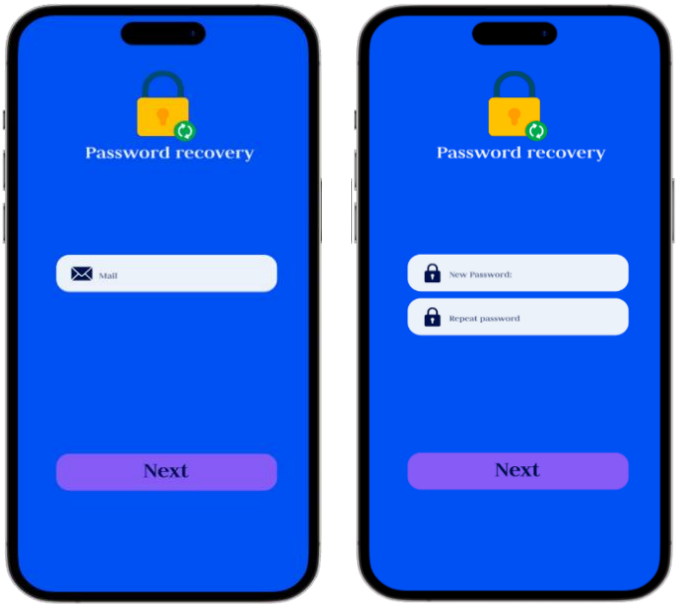



Figure 4. Register user



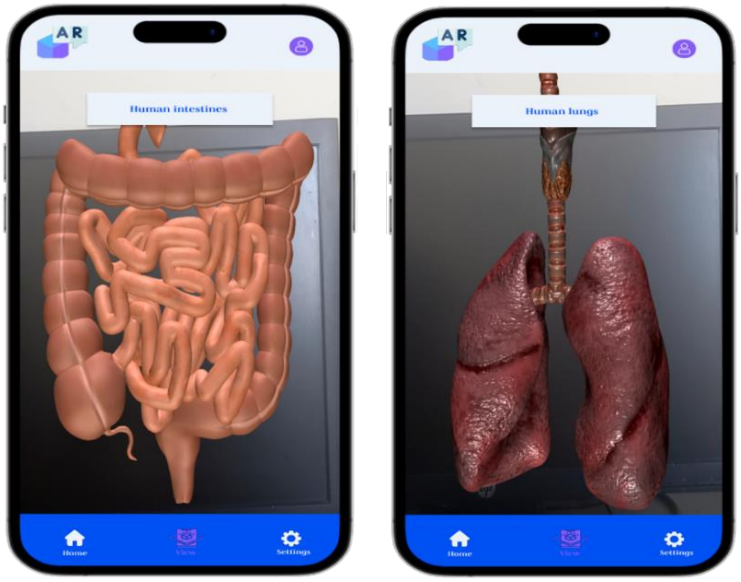

(a) (b)

Figure 5. Password recovery (a) user mail and (b) new password

The graphical representation in Figure 6 provides an initial view of the application startup, highlighting the main options available to the user. Among the alternatives presented are: learn human organs, learn human face parts, learn human teeth names, and learn human body parts. In this context, the user has the freedom to select the option that most interests them, allowing them to explore and experiment with AR technology based on their preferences and goals. This intuitive approach provides the user with easy access to the desired functionalities, enriching their experience with the application.

Figure 7 presents the AR mobile application designed especially for children with autism, which allows them to explore the organs of the human body in an interactive and educational way. The first section of the application, represented by Figure 7(a), details the parts of both the small and large intestine, providing a detailed, three-dimensional view of each component. The second section, illustrated in Figure 7(b), focuses on the lungs, showing their internal structure and functioning dynamically. This technological tool aims to provide an immersive and didactic experience, thus facilitating the understanding of human anatomy to this specific group of users. In addition, by integrating AR, active participation and meaningful learning is encouraged, contributing to the cognitive and social development of children with autism.


Figure 6. Selecting AR options




(a) (b)

Figure 7. AR application (a) human intestines and (b) human lungs

Figure 8 presents a fascinating mobile application with AR technology designed specifically for children with Asperger syndrome, offering an educational and stimulating tool to explore the parts of the human body in an interactive way. In the section represented by Figure 8(a), the main parts of the human face are shown in detail, including the mouth, eyebrows, ears, eyes, eyelashes, among others, thus facilitating the identification and recognition of these fundamental structures. On the other hand, Figure 8(b) focuses on the teeth, providing a clear and detailed view of the dentition, which helps to understand their arrangement and function in the mouth.

Figure 9 presents an innovative mobile application using AR, designed specifically for children with autism, which provides an interactive and educational experience. This application allows exploring in detail the parts of the face and teeth of people. In the section represented by Figure 9(a), it focuses on the body anatomy as a whole, clearly showing the arrangement of the head, hands, feet, legs, arms and the rest of the body. This complete representation allows children to better understand the organization and function of each body part, thus contributing to their education and personal development. On the other hand, Figure 9(b) details in detail the characteristics of the hands, showing the fingers and their different components, which facilitates the understanding of the anatomy of this part of the body.


(a) (b)

Figure 8. AR application (a) human face and (b) human teeth


(a) (b)

Figure 9. AR application (a) human body and (b) human hand

#### 3.2.4. Implementation

During this phase, the visualization of the points assigned by each participant is carried out, which represent the approvals granted to the AR. This stage is crucial within the process, as it allows the evaluation and validation of the interactions and elements of the AR by the users. Each point assigned reflects the participants' perception and response to the AR experience, providing valuable data to improve and refine the design and implementation of the technology. In addition, this stage facilitates the identification of areas for improvement and optimization of the user experience, thus contributing to the quality and effectiveness of the final product [30]. In this section, developers conduct a thorough evaluation of the project, assigning scores to determine the success of the AR implementation, as described in detail in Table 2. This phase is crucial for measuring the performance and effectiveness of the applied technology, providing key data for decision making and continuous improvement of the project.

Table 2. Results of the analysis

| Developer | Learning the organs of the human body | Visualize and learn the human skeleton and skull with AR | Visualize and learn about the animal with AR |
|---|---|---|---|
| Developer 1 | 93% | 97% | 95% |
| Developer 2 | 98% | 100% | 99% |
| Developer 3 | 99% | 97% | 100% |
| Developer 4 | 100% | 100% | 100% |
| Developer 5 | 99% | 100% | 99% |

#### 3.2.5. Evaluation

In this final phase of the process, a comprehensive evaluation is carried out with the participation of experts working directly with children diagnosed with Asperger syndrome. The main objective is to identify the effectiveness and impact of the project on this specific group of users. The experts provide invaluable insight into the effectiveness of the AR mobile application, assessing its accessibility, usability and benefits for children with autism. This feedback is critical to make the necessary adjustments to the project. This feedback is essential to make the necessary adjustments and improvements to ensure an optimal experience tailored to the needs of this target audience [31].

## 4. RESULTS

The results will present the satisfaction expressed by the specialists regarding the use of AR, providing a detailed overview of the advantages and disadvantages experienced, as well as a comprehensive comparison with other methodologies employed. This feedback provided by specialists will be crucial to understand the actual effectiveness and impact of AR in the context of children with autism. In addition, it will identify areas of success and opportunities for improvement in the design and implementation of the technology. This comprehensive evaluation will help the development team make informed decisions, guiding them towards continuous refinement of AR to more effectively address the specific needs of this user group.

### 4.1. Evaluation by specialists

The results obtained by the specialists will be essential for the development team to evaluate the impact of AR in the context of children with autism, as detailed in Table 3. This evaluation will consist of a brief score reflecting the effectiveness and relevance of AR for this specific user group. The specialist feedback will enable the development team to better understand how AR is tailored to the individual needs and challenges of children with Asperger's. It will also provide them with critical and expert insight into the usability, therapeutic and educational potential of the technology in question.

### 4.2. About the methodology

#### 4.2.1. Advantages

ADDIE methodology offers a systematic and flexible structure for instructional design, ensuring alignment with learning objectives and user needs from the outset. It facilitates early identification of problems and implementation of corrective measures to maintain high quality standards. By integrating continuous evaluation, it allows for adjustments and improvements that ensure program effectiveness over time. It promotes collaboration among stakeholders, enriching the creative process and ensuring a multidisciplinary perspective. Its adaptability allows changes to be made as needed during development, ensuring continued program relevance and effectiveness. In addition, by minimizing wasted costs and resources, it contributes to an efficient and successful implementation of the educational program.

Table 3. Results of the evaluation

| Involved | Does it improve the concentration of the child with autism? | Is this AR ideal to be presented in any educational sector, hospitals and clinics in the country? | Is the social interaction with the activities efficient? | Does the application of AR reduce the child's stress? |
|---|---|---|---|---|
| Teachers | 98% | 97% | 99% | 100% |
| Neurologist | 88% | 99% | 88% | 88% |
| Clinical psychologist or psychiatrist | 92% | 95% | 93% | 92% |
| Speech and language therapist | 95% | 95% | 88% | 95% |
| Occupational therapist | 97% | 98% | 97% | 98% |
| Special education Specialist | 95% | 95% | 93% | 95% |
| Parents | 94% | 95% | 99% | 98% |

#### 4.2.2. Disadvantages

A disadvantage of the ADDIE methodology is its linear and sequential approach, which can result in rigidity and lack of adaptability to sudden changes or emerging needs. This structure can lead to delays in program delivery, especially in environments that require agile responses. In addition, the entire process can be time-consuming and costly, as each stage must be completed before moving on to the next, which can discourage experimentation and creativity in instructional design. The need for extensive analysis can lead to paralysis by analysis, delaying the start of actual program development. In addition, the methodology may be less suitable for projects of short duration or requiring rapid and frequent iterations. Finally, the model's inherent lack of flexibility may make it difficult to apply in environments were learning needs change rapidly.

#### 4.2.3. Comparison

ADDIE is a sequential and linear approach to instructional design, while Kanban is a visual and flexible method for managing projects. While ADDIE follows a fixed sequence of stages, Kanban allows for rapid and continuous changes depending on the demands of the project. ADDIE is more suitable for projects with well-defined and stable requirements, while Kanban is ideal for environments where needs and priorities may change frequently. Kanban encourages collaboration and real-time adaptability, while ADDIE emphasizes meticulous planning and evaluation at every stage of the development process. Likewise, the Scrum methodology is an iterative and incremental agile framework for project management that prioritizes adaptability and continuous delivery of functionality by showing high quality collaboration and constant communication among team members.

## 5. DISCUSSIONS

This project aims to develop a mobile application aimed at children with Asperger syndrome, with the purpose of improving their learning in Anatomy and social interaction skills through AR technology. This approach is related to several authors, as evidenced in the work of [15], where the development of a mobile application with machine learning designed for children with dyslexia is described, addressing aspects such as reading, word decoding, comprehension, memory, writing, spelling, and speech. It is highlighted that this application has been considered an effective strategy to capture the attention of children with learning difficulties. In addition, Hussain *et al.* [18] has implemented AR in activities aimed at dyslexic and dysgraphic children, presenting a series of games that allow strengthening knowledge in an interactive way. Yousef [19], has explored the innovative use of AR in children's education, as evidenced in the presentation of the solar system in 2D and 3D images, highlighting that this technology overcomes the limitations of traditional teaching and manages to capture the student's attention effectively. These authors support our approach, highlighting the effectiveness and satisfaction that AR offers as an educational tool to address various learning problems.

## 6. CONCLUSION

The project dedicated to children with Asperger's syndrome achieves its central objective by presenting an AR development that proposes anatomy games to enhance their learning and capture their attention effectively. The ADDIE methodology was successfully employed in this project, allowing to identify the needs of the developers and to adapt the creation process according to the team's experience. In addition, continuous feedback of the software was incorporated throughout its evolution, which proved to be effective in

understanding user needs and improving the quality of the product. However, a main limitation of the project lies in the lack of a framework for organizing the team in the planning phase, which could have affected the efficiency and coordination of the project. As a proposal for future work, the integration of artificial intelligence and virtual reality is suggested to enrich the user experience and take advantage of technologies with greater impact in the educational and learning environment. This approach would allow exploring new ways of interaction and personalization of content, thus improving the effectiveness and satisfaction of the end user.

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