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Development of a Virtual Reality Application: Discussion on the Tools Used in the Context of Students with Special Educational Needs

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ABSTRACT
This article explores the development of a Virtual Reality application aimed at Basic Education students with special educational needs, particularly those diagnosed with Developmental Dyscalculia, Cerebral Palsy, or Visual Impairment. The work discusses the tools and methodologies employed in creating the virtual environment, focusing on the use of the Unity engine for development, Blender for 3D modeling, and the integration of specific accessibility features. The implemented challenges are presented and analyzed, such as activities directed toward teaching the Pythagorean Theorem and concepts of balance, aiming to adapt learning to the individual needs of the students. Furthermore, it highlights the importance of pilot tests to refine the application's functionalities, ensuring its effectiveness as an inclusive educational tool. Finally, it emphasizes the need for ongoing research to enhance the use of assistive technologies in Inclusive Education, promoting more accessible and meaningful learning.

Keywords
Application; Virtual Reality; Special Educational Needs; Accessibility.

ACM Classification Keywords
H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities; H.5.2 [User Interfaces]: User-centered design; Graphical user interfaces (GUI); K.3.1 [Computer Uses in Education]: Computer-assisted instruction (CAI); K.4.2 [Social Issues]: Assistive technologies for persons with disabilities; I.3.7 [Three-Dimensional Graphics and Realism]: Virtual reality.

INTRODUCTION
Technology is one of the most important tools in today's society. The development of new technologies is essential to improve quality of life and enable innovations in various areas such as health, education, and the environment.

In 2024, it is common to find Technological Resources (TRs) that facilitate access to various situations. The cellphone, for example, has replaced physical money, driver's licenses, and even identification documents. Currently, it's rare to find people who use cash to pay their bills; instead, using a cellphone for this purpose has become commonplace—a situation that would have been unusual in 2020, for example.

In this context, it's normal to say that TRs, widely used in our daily lives, are also common in areas like Education. However, the concept of TRs is broad and even includes simple objects like pens, pencils, and notebooks. Therefore, understanding the potential of TRs, how they are categorized, and how they are developing is essential for us to continue producing innovative technological instruments that contribute to the enhancement of Education.

"If the school does not include new technologies in the education of new generations, it is going against the tide of history and, above all, producing a form of social exclusion" (our translation) [8]. That is, it's not enough just to have technology; education and other areas need up-to-date technology that keeps pace with societal development and meets the skills and needs of 21st-century students [8].

Technology in the field of Education, particularly for Inclusive Education, offers a wide range of possibilities for application and innovation. Among these is the possibility of creating tools that address special educational needs (SENs), which is real and constantly developing. It's common for applications and instruments to emerge that assist students, workers, doctors, lawyers, and others in performing tasks that are sometimes very difficult or even impossible for certain groups. The wheelchair itself is an example of how technology can benefit and assist people toward a better quality of life, as it creates conditions that enable the user to compensate for some type of functional limitation, whether motor or intellectual [1].

With the increased production and use of specialized technological resources in recent years, various terminologies have emerged to refer to this area, such as "Assistive Technology (USA), Assistive Technology

(ICF/WHO), Support Technology (European Commission/EUSTAT), and Technical Aids (Ministry of Health)” (our translation) [9].

Although, according to Rocha and Catiglioni [9], there are various terms for Technologies that can assist individuals with SENs, this study uses the term Assistive Technology (AT), defined by the Brazilian Law for the Inclusion of Persons with Disabilities as: “…products, equipment, devices, resources, methodologies, strategies, practices, and services that aim to promote functionality related to the activity and participation of a person with a disability or reduced mobility, aiming at their autonomy, independence, quality of life, and social inclusion” (our translation) [3].

It is expected that the development of technologies in the field of Education, especially in Inclusive Education, will allow for the continuous enhancement of teaching and learning processes, enabling everyone to achieve a better quality of life and greater equality of opportunities. With the advancement of ATs, Inclusive Education becomes more accessible and qualified, meeting the special needs of each individual.

For some students with disabilities, the use of ATs has become fundamental to facilitate access to knowledge and promote the development of their skills, being “…one of the most appropriate ways to have access to knowledge, with the aim of enhancing their abilities and cooperating in their studies, communication, and interaction with others” (our translation) [1].

Among the possibilities of ATs used in education, the use of immersive Virtual Reality (VR) applications stands out. The immersion provided by VR can be adapted to meet the specific needs of each student, offering a safe space where the student can explore without the risks present in physical environments. This feature is even more important for students with motor, sensory, or cognitive difficulties, as they may encounter challenges in accessing traditional educational content.

Furthermore, immersive virtual environments enable the personalization of learning, allowing educators (or the student themselves) to adapt scenarios and activities according to the student's pace and individual needs.

With this perspective, the Study and Research Group on Developmental Dyscalculia of the Pontifical Catholic University of Rio Grande do Sul (GEPEDPUCRS) has been developing studies aimed at creating interventions that contribute to the learning of students with Developmental Dyscalculia (DD), expanding in the last two years to include students with Cerebral Palsy (CP) and Visual Impairment (VI), through a research project entitled Science and Mathematics Learning of Inclusion Students in Basic Education: Implications from the Design and Development of Mixed Reality Applications, with financial support from the National Council for Scientific and Technological Development (CNPq). The main objective of the project is to understand how the use of VR applications impacts learning in Natural Sciences and Mathematics for Basic Education students diagnosed with DD, CP, or VI. To this end, a VR application is being conceived within the GEPEDPUCRS and developed by researchers from the group.

This article presents an excerpt from this project, aiming to disseminate and discuss the tools used in developing this VR application designed for Basic Education students diagnosed with DD, CP, or VI.

Thus, it addresses the stages of conception and development of the application, which include theoretical and practical preparation of the developers; search for the most suitable software for creating the environment and for 3D object modeling; choice of accessibility resources; environment and challenges for pilot testing.

The team participating in this project consists of master's and doctoral students in Education with backgrounds in Mathematics, all members of the study group GEPEDPUCRS, and undergraduate research fellows from the Psychology and Computer Science courses. A master's student and the Computer Science students make up the application's development team.

THEORETICAL AND PRACTICAL FOUNDATIONS NECESSARY FOR THE DEVELOPMENT OF THE APPLICATION

To begin developing a VR environment that has functional characteristics to meet the needs of students and educators, it is important to decide which engine will be used and how it works. Unity was chosen, which requires the C-sharp (C#) language for its development.

Unity, launched in 2005 by Unity Technologies, has established itself as one of the most popular game development engines on the market, alongside Unreal Engine. Initially developed to democratize game creation, Unity offers a versatile platform that supports a wide range of devices, from consoles and computers to mobile devices and emerging technologies like Augmented Reality (AR) and VR. With it, developers can perform everything from 3D modeling and animation to the implementation of complex physics and artificial intelligence (AI). Unity integrates mathematical and physics libraries, such as rigid body dynamics and force simulations, where knowledge of vector mathematics and linear algebra is fundamental for the development of environments and the actions and reactions developed.

When comparing Unity with other platforms, such as Unreal Engine, it is important to consider the learning curve and the development flow within the platform. Unreal is often preferred for games that require ultra-high-fidelity graphics, while Unity is recognized for its ease of use and support for a wide variety of platforms. In this sense, the choice of Unity was unanimous by the team, as the learning and development process would be relatively easier. According to Alves [2], Unity "…practically dispenses with the use of programming codes; all you need to do is define some properties and actions that must be executed according to the occurrence of a certain event".

To develop in Unity, it is essential to have adequate hardware. The minimum recommended is a quad-core processor, 8 GB of RAM, and a graphics card compatible with DirectX 11. These components ensure that the developer can work smoothly, without compromising performance during the development of games or applications. Although these requirements are the minimum for the correct functioning of Unity, having better hardware enhances the process, making creation, rendering, and development faster and more efficient. This resource was acquired through financial support provided by CNPq.

Regarding the programming language used, C-sharp is a programming language developed by Microsoft, launched in 2000 as part of the .NET framework. Its syntax is influenced by C and C++, combining the efficiency of low-level languages with the simplicity and security of high-level languages. Originally used in enterprise applications and web development, C# has become the standard language for development in Unity due to its integration with .NET and its robustness in memory management and code execution.

Compared to other languages, such as Java and Python, C# stands out for its strong support for object-oriented programming. The language offers a clear structure for defining classes, methods, and variables, allowing developers to create structured and modular systems in Unity. Moreover, the static typing of C# facilitates early detection of compilation errors, providing greater security and efficiency in the development process.

"A robust language with years of support and widely adopted by the professional software development market is C# (pronounced 'C Sharp'). C# is a modern, robust, and object-oriented programming language that is constantly evolving and being adopted by professionals worldwide. With this programming language, it is possible to create software for many types of applications such as cell phones, personal computers, games [...]" (our translation) [4].

Programming in C# involves creating classes that can contain variables and methods, establishing logical relationships between different parts of the code. This allows developers to define complex behaviors and interactions between objects within a game or application. C#'s ability to support object-oriented programming makes the code more modular, which is essential for large and complex projects, such as those developed in Unity.

To create scripts in the C# language, it is necessary to use an IDE (Integrated Development Environment), which is an environment that allows writing in this language. When installing Unity, you will be prompted to install Visual Studio Code, which, although not a complete IDE, allows for debugging of C# code among other functionalities.

In addition to the engine and the language, it was necessary to learn how to use the source code hosting platform known as Git. This platform allows developers and teams to collaborate on software projects, storing, managing, and sharing code. Developers manipulate the code and develop the environments; then, what has been developed is inserted into a base environment that will relate to other environments and challenges.

Added to this was the need to use 3D modeling software for the development of the environment. Although Unity enables 3D modeling, Blender was chosen as the software for developing some items in the environment. Besides being free, Blender is open-source software, meaning it is continuously improved by a community of developers worldwide. It features a complete range of tools for 3D modeling, including digital sculpting, polygon modeling, curve creator, and smooth surfaces. In this sense, modeling in Blender offers many advantages over modeling in Unity, mainly due to the quantity and variety of editing tools available. However, creation in Blender and subsequent import into Unity require some care, such as the scale used in creation, as it influences the source codes for positioning and movement in Unity.

Besides the software, it is important to highlight the need to understand the SENs of each student to bring out the most important aspects that need to be considered regarding DD, CP and VI. To this end, analyses of the anamneses with the parents/legal representatives of the target students of this research are being conducted, as well as theoretical readings about each of these educational needs and psychological, arithmetic, and problem-solving tests to outline the profile of each student participating in the project.

Among the different needs that are being found by the research group members, the following stand out: the use of strong contrasts between the colors of objects to facilitate the distinction of objects within the environment (VI); auditory feedback from actions performed as well as interactions with the environment and objects (VI) [10]; playful and concrete challenges with repetition and progress according to the user's percentage of correct answers (DD); assistance with motor precision in movements and challenges, and an intuitive interface that allows the repetition of commands and activities (CP) [5, 6, 7].

VIRTUAL ENVIRONMENTS AND CHALLENGES

Up to this point, four mathematical challenges are being finalized, addressing content studied in Elementary Education, mainly from the 6th grade onwards, which will compose the application titled as: Pythagorean Theorem Puzzle; Maintaining Balance; Riding the Elevator; and Solving Problems with the Fractional Ruler.

It is worth noting that, as it is still under development, the design of the activities still needs improvement. At this moment, the development is in alpha testing, meaning the team is constantly testing and seeking to detect functional issues, bugs, and system errors. This stage aims to eliminate as many errors as possible before exposing the product to the students who are our external audience.

Pythagorean Theorem Puzzle

The developed mathematical challenge is based on the Pythagorean Theorem, which states that in a right-angled triangle, the sum of the areas of the squares constructed on the two legs is equal to the area of the square constructed on the hypotenuse. This concept was implemented in a three-dimensional environment, allowing students to interact with the components and understand the application of the theorem in a practical way.

To create this experience, 3D modeling of the components was used, such as the cubes on the sides of the right-angled triangle. Additionally, Unity's Rigidbody and XR Socket Interactor components were employed. The use of Rigidbody was to apply physical laws to the objects, while the XR Socket Interactor allowed the pieces to fit into the correct places, facilitating interaction, especially for students with fine motor skill difficulties.

The challenge presents a progression of difficulty, starting with assembling the smaller squares, as shown in Figure 1.

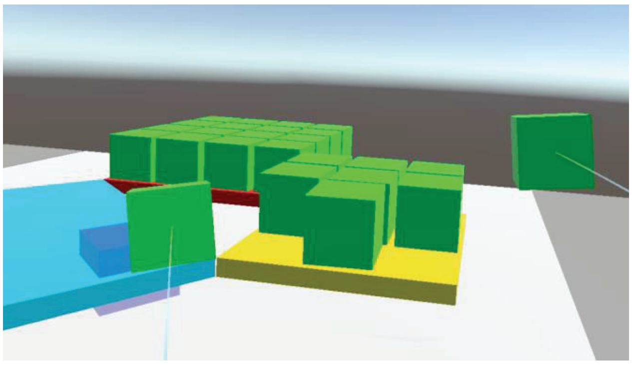

Figure 1. Image showing the development of the first stage of the Pythagorean Theorem puzzle challenge.

Before starting the challenge, students will, through auditory devices, hear the history of the resolution of right-angled triangles by different civilizations and the origin of the Pythagorean Theorem. Then, instructions will be given visually and audibly. Students will have 25 identical cubes available from which they will have to assemble the squares of the legs, one with nine cubes and the other with 16 cubes, as can be seen in green in Figure 1. Once done, they will receive auditory feedback signaling the end of the first stage. Next, they should construct the square of the triangle's hypotenuse from the two smaller squares already built. After solving the classic challenge of assembling the Pythagorean triangle with sides 3, 4, and 5, the challenge will use other pieces for this activity. This time, five geometric figures of different shapes will be available, as shown in Figure 2. The yellow square represents the square with side 3, while the red, blue, green, and orange pieces together represent the square with side 4. After assembling the two smaller squares with these pieces, the student will be challenged to assemble the square with side 5 using all the pieces.

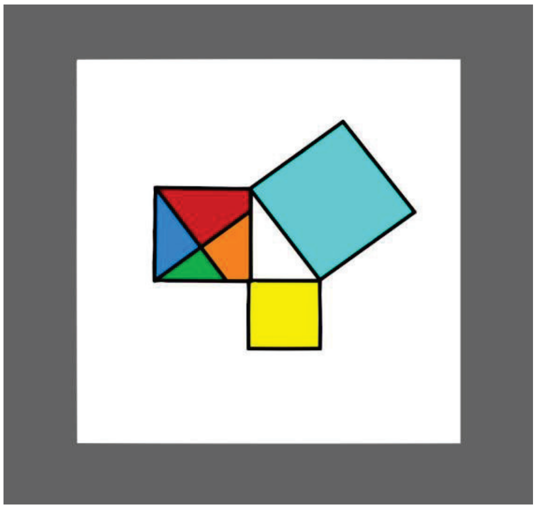

Figure 2. Image representing the second stage of the Pythagorean Theorem puzzle challenge.

Finally, a new puzzle possibility will be presented in the third stage of the challenge, with the same objective of geometrically demonstrating that it is possible to construct the larger square from the two smaller ones. Similar to the second stage, seven figures of different geometric shapes will be on the virtual table for the student to construct the two smaller squares. Then, through visual and auditory instructions, they will be informed that all pieces should be used to construct the larger square (Figure 3).

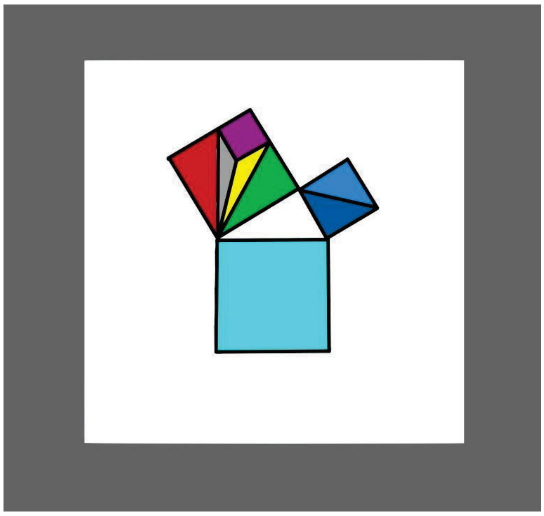

Figure 3. Image representing the design of the third stage of the Pythagorean Theorem puzzle challenge.

In this way, the challenge reinforces the understanding of the Pythagorean Theorem and stimulates spatial reasoning and problem-solving in an interactive environment.

Some students with DD have difficulty handling manipulative materials and deficits in abstracting concepts, as do most students with CP. Thus, manipulating objects using devices like the third-generation Oculus Touch, in addition to Unity's XR Socket Interactor, contributes to the execution of this task because it allows users to interact with objects more easily. This tool allows the user to move, grab, and place objects even with less motor precision, as the locations where these objects will be used have already been predetermined by the developer, and the tool helps to place them in these locations. In addition, the color layout, auditory instructions, and the possibility of zooming in on the modeled objects will assist students with VI in completing the challenge.

Maintaining Balance

The "Maintaining Balance" activity was conceived as an inclusive digital pedagogical resource, aiming to facilitate the learning of fundamental physical concepts, such as the balance of forces, through an interactive simulation of a two-pan balance scale. In the educational context, the central purpose of this activity is to promote a practical understanding of the concept of equality, helping students comprehend numerical relationships and, as they advance, the notion of equations. By interacting with the simulation, students can manipulate weights of different masses and observe how this affects the balance of the scale. This practical approach is particularly valuable for students with DD, who often encounter difficulties in abstracting mathematical concepts. For these students, the simulation offers a concrete way to visualize and experience balance, aiding in the internalization of the concept of number and inverse operations. For students with CP, it enables the handling of manipulative materials that they would hardly be able to use with real objects.

The development of the "Maintaining Balance" activity followed a detailed programming process, applying essential mathematical and physical concepts to ensure a precise and educational simulation. The initial structuring phase included modeling the main objects of the simulation, such as the balance scale, supports, pans, and weights (Figure 4). These elements were modeled using 3D design software known as Blender.

To simulate the physics of the objects, components such as Rigidbody and ArticulationBody in Unity were employed. The Rigidbody component allowed the objects to react to forces like gravity and collisions, while the ArticulationBody was used to model the joints of the balance, specifically the joints that enable the rotation of the beam in response to the weight difference between the pans. Proper configuration of these joints, such as the Revolute Joint, was necessary to ensure that the beam rotated correctly around a fixed axis, reflecting the equilibrium of the acting forces.

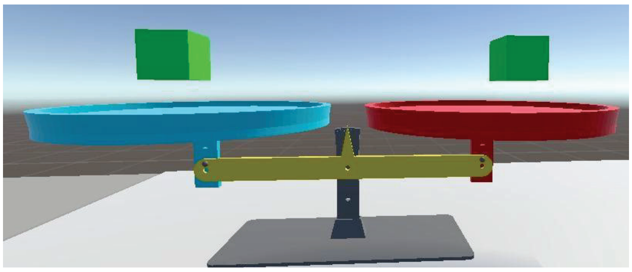

Figure 4. Image of the development of the balance scale.

The programming of the simulation involved applying mathematical concepts such as linear algebra and trigonometry. Linear algebra was used to calculate the transformations and rotations of the objects, while trigonometry assisted in determining the inclination angles of the beam in response to the weight difference between the pans. These calculations helped accurately simulate the behavior of the balance, ensuring that the beam tilted appropriately, with the heavier pan descending and the lighter pan ascending, as expected.

The logic of the beam's rotation was implemented through direct manipulation of the ArticulationBody component. Programming in C# allowed for controlling the rotation of the beam based on the weight difference between the pans.

From the student's point of view, the challenge increases in difficulty as they progress through the tasks, all of which relate to the balance of the scale. When viewing the challenge bench, the student will have the audio option to listen to the history of equation solving. In the first stage, the student will solve problems aimed at creating numerical relationships, demonstrating flexibility of thought regarding number construction. In one of the pans of the balance, a quantity will be presented, and they will be challenged to make combinations of quantities that keep the balance level. For example, if the first pan has eight cubes, they will have combinations of other quantities available on a bench and will need to decide which ones total eight: 1+7; 2+6; 3+5; 2+2+4; 3+1+4; 3+2+3; among other possible combinations (Figure 5).

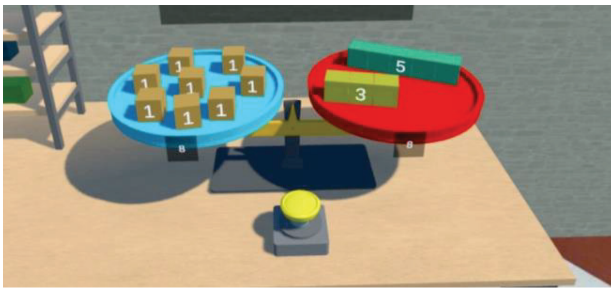

Figure 5. Image of the challenge to construct the quantity 8.

In each of the challenges, the student will receive auditory feedback indicating their success and guiding them to the next challenge.

In the next stage of the challenge, the student will be introduced to solving first-degree equations. The challenge will appear, and through auditory and visual devices, they will receive instructions to discover the weight of cube x (Figure 6).

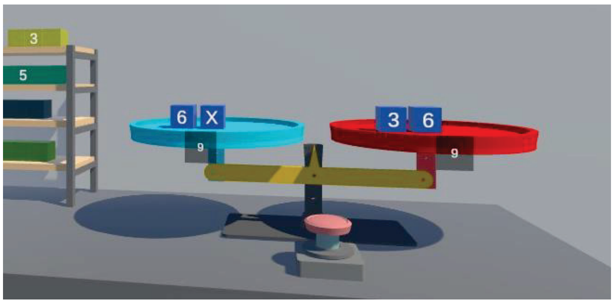

Figure 6. Image of the equation-solving challenge.

In the example of Figure 6, through strategies, the student should solve the equation $x + 6 = 10$. The aim is for them to realize that to maintain balance, it will be necessary to perform the same operation on both pans. The level of the equations will increase in such a way that they understand that to maintain balance, they need to subtract the same amount from both pans or equally divide the presented quantities—in other words, to abstract the use of inverse operations to isolate the weight of x on only one of the pans of the balance.

Thus, as in the previous challenge, these activities and layouts were designed considering the individual characteristics of the students, taking into account the limitations caused by DD, CP, or VI. Therefore, the simulation interface is being designed to be accessible, including customization options to meet different needs. For example, the statements will include the possibility of adjusting contrast and font size, facilitating visualization for students with visual impairment. Additionally, the auditory instructions were designed to be clear and objective, allowing them to follow the challenge autonomously.

Going Up the Elevator

The elevator activity consists of an adaptation of the classic logic exercise about crossing a river with a sheep, a sack of lettuce, and a dog, which dates back to medieval times from the manuscripts of Alcuin of York. However, there are some problems developed with this same logic, such as the boat problem: the boat can only carry you and one more object or animal, considering that certain combinations cause problems, like the dog and the sheep, which if left together will conflict, or the sheep and the sack of lettuce, where if left together, the sheep eats the food.

For the application, the adapted challenge takes place in an elevator, where the student's goal is to take their pets to the second floor of a building, but with the same combination problems as the river activity. In the activity, the "player" has a hamster, a cat, and a dog, which, although they get along well inside the apartment, become agitated and make a mess when they are outside the home. The hamster and the cat cannot be left alone together, nor can the dog and the cat (Figure 7).

As in the previous challenges, when viewing the challenge station, the student will have the audio option to listen to the story about the origin of the problem and then will receive instructions with both visual and auditory options. Through these instructions, it will be necessary to create strategies and use logical reasoning to define a plan of action capable of taking all the animals to the second floor in such a way that there is no confusion inside the elevator.

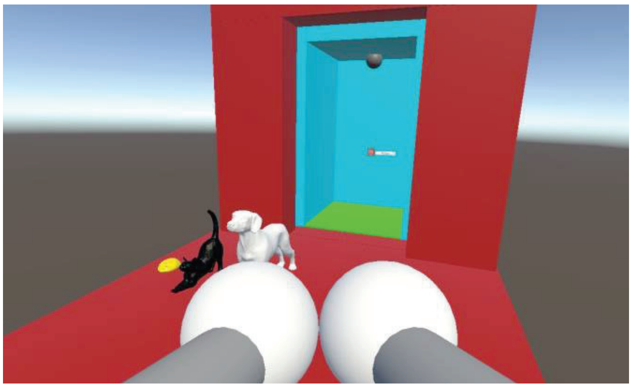

Figure 7. Image of the development of the elevator challenge.

For the programming of the problem, the modeling of the elevator and prototypes for the animals was first done to provide a visual basis for the problem, using the resources provided by Blender and Unity itself. Blender was necessary to create and model the animals that will be used. Due to requiring greater detail in these models, Blender was the better option.

Unity was used to create the elevator and the other objects. Then, scripts were made using Visual Studio, which is Unity's standard code editor, enabling the elevator to receive two elevation points and move between them when the user presses a button inside it. Next, collision boxes were created to recognize the animals positioned within them—one on the initial floor, another on the final floor, and one inside the elevator. For the challenge to be successfully completed, all three animals should be taken to the 3rd floor.

The script will check if the spaces with collision boxes have the correct characters. Placing two characters that cannot be left together will trigger a negative auditory and visual response; if the student manages to complete the activity and take all the animals to the upper floor, a sound and visual signal representing success will be emitted. There is not yet a plan to increase the complexity of the challenge, but it is possible by adding another type of animal. However, the goal is to maintain the reasoning and plan of action necessary to solve the classic problem.

Solving Problems with the Fractional Ruler

Using visual and auditory resources in VR, an adapted model of a fractional ruler is being developed to assist students in learning and studying fractions. Currently, the model under development consists of two tables aimed at solving different problems with fractions that have numerators and denominators ranging from 1 to 12. The fraction activities to be worked on at these tables are identification, comparison, and equivalence problems (Figure 8) and operations with fractions (table 2). In the control interface of the table, initially, the numerator is limited so as not to exceed the denominator, as the goal is to start with simpler fraction concepts and gradually progress to more complex ones, avoiding improper fractions at first. The second table is still under development, with no fraction operation questions yet.

Figure 8. Image of the development of Table 1 of the Fractional Ruler.

The table used for comparison, identification, and equivalence problems consists of two fractional pieces and a control interface with five buttons—four of them being regulators of the numerator and denominator, and one being the answer confirmation button—and a display that shows the fraction selected by the user. One of the fractional pieces has its value defined by the user through interaction with the control interface buttons, and the other is based on a question system. With this table configuration, we can carry out a series of fraction exercises, which include fraction comparison and identification questions, as well as equivalence exercises.

To solve the identification problems, a table will be presented to the student with two fractional pieces: one predefined based on the question system and the other to be defined based on the user's inputs. The goal of the student/user is to correctly identify the fractions that will be randomly generated by the question system. If the fraction is incorrectly identified, there will be auditory and visual feedback indicating the error. Once the correct fraction is entered, auditory and visual feedback will indicate success and proceed to the next problem. As the student correctly solves the problems, the number of correct answers in the elaborated question system increases, and as the student gets it right, the denominator's value progressively increases until it reaches the maximum value of 12.

All this system of five buttons, as well as the text window created from Unity's user interface, will create conditions where the student needs to handle each piece of the fractional ruler—an activity often made impossible by the motor limitations of a student with CP. Moreover, all the limitations that text can present to a student with VI can be mitigated.

ANALYSIS OF FUNCTIONALITIES

Among the functionalities planned for this VR application, the main one is the sensation of immersion. The experience intended to be created after the completion of these challenges is contact with an environment inspired by an interactive museum, specifically the Science and Technology Museum of PUCRS (MCT-PUCRS). When the student puts on the 3D glasses, they will visualize the entrance hall of the MCT-PUCRS and, as they move, will be able to see elements similar to those they would find inside the museum. Then the student will enter different rooms where they will find each table with the challenge.

The 3D modeling of the environment will be done using tools like Blender, Unity, and assets that have already been created and made available to the community. The goal is that through visual, auditory, and tactile effects, it will be possible to simulate part of the real environment found at MCT-PUCRS.

Another functionality is interaction. Students with CP and VI often cannot manipulate real objects. For this project, with support from the CNPq, three Meta Quest 2 headsets with touch controls were acquired. In the virtual environment, the student will be able to adjust their perspective in each of the challenges using their movements with the controllers, which will allow them to bring each object closer or further away.

Considering that each challenge will not have a time limit for its execution and completion, the student will be able to make precise simulations, going back and forth in the strategies created.

A third functionality is entertainment. In addition to enabling a tour within the context of a museum, the student will be able to explore the challenges in a playful and interactive way, focusing on learning but with a fun approach. Addressing content through practical activities will make the teaching process more engaging.

Furthermore, the environment will integrate different accessibility resources, such as contrast adjustments, audio guides, and adapted control options. These functionalities ensure that all students, regardless of their specific needs, can participate inclusively.

In addition, the application can be used individually or with more students simultaneously, making social interaction possible. Although this application is being designed based on the profiles of students with DD, CP, or VI, it can be used by students who do not have SENs, creating an environment of inclusion and interaction in the classroom.

Finally, education stands out as one of the functionalities, as the application will allow students to explore mathematical concepts in a more practical, interactive, and gradual way, making it possible to overcome cognitive and physical challenges that are not always possible to minimize in the classroom.

FUTURE WORK

Evaluating the usability, interface, and interaction of the application by students and teachers is essential to ensure it meets user needs. This evaluation will be conducted through individual interventions, during which each student and teacher will use the application after the implementation of the challenges and the completion of the environments.

Currently, both the challenges and environments—the design of objects and the user interface—are under development and are being created from the perspective of master's and doctoral students and Psychology undergraduates, based on the responses given in the anamnesis and the results of the tests conducted.

It is worth noting that the alpha test has been focused on collecting feedback from team members and adjusting errors and problems that may arise to tailor the application to the group's specific needs.

Once the four challenges are completed, the evaluation will be conducted as a beta test, collecting feedback from students and their teachers, providing important data on the challenges and the necessary adaptations for qualification. In this phase, the software will be made available to a larger group of users who will provide real feedback—in this case, students and teachers participating in the research. The tests will be conducted by researchers involved in the project, but not by the programmers, in an already compiled environment—that is, without control, under real usage conditions. All feedback will be recorded for the purpose of improving the environment. The goal of this evaluation is to identify improvements for the environment and the application.

Additionally, continuous feedback from students and educators will be important for enhancing future challenges. The results of the alpha and beta tests will help assess the potential of the virtual environment as an effective tool in developing mathematical skills in students with DD, CP, and VI.

FINAL CONSIDERATIONS

This research highlights the importance of detailed planning regarding the tools that were and are being used in the development of a VR application designed for students with SENs. The use of Unity has proven adequate for creating an interactive learning environment and enables the development of important functionalities for students with DD, CP, and VI.

The application of complementary software, such as Blender, and attention to accessibility needs stand out as important components for building an inclusive and functional environment. Although it is still in the development phase, initial tests and feedback obtained from pilot tests will be crucial to refine the application's functionalities, ensuring its continuous improvement.

As the development of the environment progresses, it is important to continue collecting feedback from students and educators to improve the application's functionalities and ensure that it fully meets pedagogical expectations and user needs.

Finally, it is important that new research is conducted in this area to expand the understanding of best practices in the development of AT and VR aimed at Inclusive Education. The continuous advancement of these technologies can provide increasingly effective and accessible tools, allowing students with SENs to have more meaningful learning experiences. Collaboration among developers, educators, and researchers will be fundamental to identifying new challenges and opportunities, ensuring that these technologies keep pace with constantly evolving pedagogical and social demands.

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