

## Article

# A Method to Develop Accessible Online Serious Games for People with Disabilities: A Case Study

Angel Jaramillo-Alcázar <sup>1,\*</sup> , Paz Cortez-Silva <sup>1</sup>, Marco Galarza-Castillo <sup>1</sup>  and Sergio Luján-Mora <sup>2</sup> 

<sup>1</sup> Facultad de Ingeniería y Ciencias Aplicadas, Universidad de Las Américas, Quito 170125, Ecuador; maria.cortez@udla.edu.ec (P.C.-S.); marco.galarza@udla.edu.ec (M.G.-C.)

<sup>2</sup> Department of Software and Computing Systems, University of Alicante, 03690 Alicante, Spain; sergio.lujan@ua.es

\* Correspondence: angel.jaramillo@udla.edu.ec; Tel.: +593-99-837-2323

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**Abstract:** Video games that are used as teaching tools are called serious games. However, there is an important factor that is not usually considered in the design of serious games— the inclusion of people with disabilities. Inclusion can be reached only if accessibility takes on an important role for all. On the other hand, new trends have resulted in different smart devices being used in classrooms. These devices also allow for applications, such as serious games, to be used to support people’s learning process. Despite this, these applications are generally not multi-platform and do not usually consider accessibility features for people with disabilities. This paper proposes a method to develop accessible online serious games that consider people with disabilities as potential users. The method is applied in the case study of an online serious game that teaches about the architecture of a computer in a fun and entertaining way. The method also presents and describes several guidelines to improve online serious game accessibility for people with disabilities. Finally, tests are conducted with some users to gather information about the online serious game and the accessibility features included. This study has important implications for the development of learning tools that consider people with disabilities.

**Keywords:** accessibility; disabilities; educational; impairments; learning; multi-platform; online; serious games

## 1. Introduction

Nowadays, technology is an active part of people’s daily lives, including teaching–learning processes. Many educational institutions support their teaching processes through the use of technology [1].

Around the world, there are many people with disabilities and every year they increase in number. Approximately one billion people live with some type of disability, which corresponds to 15% of the world population [2]. It is important to emphasize that this percentage will increase due to the ageing of the world population [3] and that each one requires equal conditions at any level of their education. Additionally, it is important to consider that with such a high number of possible users for software, it would be illogical to ignore the fact that accessibility features can increase the scope of an application as well as improve its versatility.

Beyond being just a matter of extra features, accessibility should be considered as the parameters or even the minimum requirements that need to be met in the development process of any type of software [4]. For example, there are many government information systems that are of great importance to the inhabitants of a nation. The access and ease of use of these platforms is not only

a matter of comfort or luxury, but a necessity and even a right. When a patient intends to access a medical appointment in the public health system, for example, a process that makes mandatory use of technology must be followed. People with disabilities comprise a group that needs to access the services of health systems in a more periodic way than other groups. To develop software that does not include accessibility features is contradictory.

There are cases of governments that have already taken action on the matter. The European Parliament and the Council of the European Union, for example, published a directive on the accessibility of the websites and mobile applications of public sector bodies [5]. Additionally, in the US, Section 508 requires federal agencies to ensure that their information and services are accessible to people with disabilities [6].

On the other hand, the growth of people with disabilities has led to initiatives that promote accessibility as an important feature in the world around us [7] and serious games are not the exception. Serious games is a category of video games designed with the purpose of supporting the educational process [8]. Serious games is the most applicable term and aligns with what is intended to be achieved with this project. It consists of giving the characteristic of “serious” to a game using playful techniques (scores, levels, prizes). This technique allows people to design games that aim to teach some specific theme and not just entertain. For example, “NoCredit, GameOver”! (NCGO) is a mobile game to teach the players how to decrease their debts [9].

Likewise, ageing and serious games are part of the educational process and together support the life long learning process [10]. It is important to consider that the educational process is not only for young people, but also includes a re-education process in older people who have more disabilities due to ageing. There are many areas of knowledge where serious games have been applied: medicine [11], engineering [12], training and education [13], programming [14], business and industry [15], nursing education [16], among others.

Many efforts have been invested in the creation and development of serious games. However, there still exists a gap in the accessibility field of that initiatives [17]. This gap can be mitigated through the serious games used in different platforms and applied to education of people with disabilities [18].

Recently, several initiatives to design accessible serious games have gained strength and importance. Thus, in [19] we have presented a serious game for people with hearing disabilities, to learn the basic principles of electronics and electricity. Additionally, in [20] we have proposed an educational game considering issues for inclusion of people with visual disabilities. Nevertheless, these works have shown that incorporating accessibility guidelines in any type of video game is challenging and this needs to be explored.

In this paper, we propose a method to develop serious online games that include accessibility features. This method considers different parameters at the video game level as well as accessibility for people with disabilities. In the development of the proposed serious game, several characteristics that allow for a high degree of inclusiveness are considered. Additionally, a case study is presented and their results are analyzed in order to assess user acceptance and the level of teaching and learning they may experience.

The rest of this article is organized as follows. In Section 2, we present a review of disabilities, accessibility in video games and concepts related to edutainment that considers game-based-learning, gamification and serious games. In Section 3, we explain the method and the parameters proposed to developing an accessible online serious game. Next, in Section 4, we present a case study where we explain its development. In Section 5, we discuss the obtained results. Finally, in Section 6, we conclude the research and we outline our future works.

## 2. Background

Serious games must be accessible to provide equal access and equal opportunity to people with diverse abilities. Moreover, the United Nations (UN) Convention on the Rights of Persons with Disabilities [21] recognizes the right of people with disabilities to education as a basic human right for all people. Governments should “ensure an inclusive education system at all levels and lifelong learning” [21].

Before anyone can create accessible serious games, they must understand the different categories of disability and how they impact the use of games. In order to better understand the method presented in this article, the characteristics of the main disability categories are summarized below, as well as the accessibility characteristics that benefit them.

Accessibility can be defined as the ability of an object to be used in spite of the condition or disability of a person [22]. In video games, accessibility is a feature that is beginning to be considered by software developers [23].

Although the majority of video games are not accessible, there are several famous video games players with disabilities who have excelled professionally. An example would be Sven Van de Wege [24] and Ben Breen [25], better known as Blind Warrior and Sightless Kombat, respectively. Both are blind and they are fighting game players. They learned the different sounds of the video games in order to play them. Another case is Adam ‘Loop’ Bahriz who is a legally blind and deaf “Counter-Strike” gamer [26]. Another example is Mike Begum, better known as BrolyLegs. Mike is a 28 year old gamer who has limited muscle development because he was born with arthrogryposis [27]. He is a top-ranked Chun-Li online player in “Ultra Street Fighter IV” and uses a special device that is controlled with his jaw. These people used some characteristics of the video game to improve their playing and enjoy a complete experience. However, these characteristics were not incorporated as accessibility features of the video games.

On the other hand, according to the GNOME developer accessibility guide [28] and the Accessible Player Experiences Patterns (APX) for designing video games with accessibility features [29], there are four disability categories that will be detailed in the following: visual disability, motor disability, hearing disability and cognitive disability.

### 2.1. Visual Disabilities

This disability is related to the sense of sight and the organs associated with it. Visual disability refers to decreased vision and according to the World Health Organization (WHO) International Classification of Diseases [30], visual disabilities can be classified into:

- Normal vision.
- Moderate visual disability.
- Severe visual disability.
- Blindness.

Within this classification there is *low vision* which is composed of moderate visual disability and severe visual disability. Thus, low vision and blindness together represent all cases of visual disabilities [31]. Another variant within the types of visual disabilities is *colorblindness*. Colorblindness is defined as a condition in which a person is not able to detect certain colors or to distinguish between red and green or yellow and blue correctly [32]. Usually, the person with color blindness perceives the world as shades of gray.

Some features have been included in some video games to improve their accessibility for people with visual disabilities. This is the case of the “Zork” series [33] and the “GMA Tank Commander” [34]. The first is a text-based game that can be played without images while the second is an audio-focused game that is largely focused on what players can hear rather than see.

So, there are video games for mobile devices that include accessibility features for people with visual disabilities. For example, “Zany Touch” [35], which integrates Apple’s VoiceOver screen reading technology so that it can be used by blind people with visual disabilities.

## 2.2. Motor Disabilities

This disability considers users who have muscle weakness, mobility problems or lack of limbs. Systems that work by voice or by the eye-tracking method are adequate solutions for this type of disability.

Motor disabilities have a variety of severity since limitations of people stamina to paralysis. These disabilities are caused by some conditions present at birth or, in some cases, as a result of illness or physical injury [36].

According to the International Classification of Functioning, Disability and Health (ICF) [37], body structures related to movement are divided as follows:

- Structure of head and neck region.
- Structure of shoulder region.
- Structure of upper extremity.
- Structure of pelvic region.
- Structure of lower extremity.
- Structure of trunk.

Due to the body structures described, some motor disabilities are generated, such as tetraplegia, paraplegia, among others. On the other hand, some initiatives have been generated to develop accessible video games for people with motor disabilities. For example, in [38], the authors present a video game controlled by a brain–computer interface that simulate a wheel-chair training. Additionally, in [39] a sudoku video game is presented. Both video games are focused on people with motor disabilities.

## 2.3. Hearing Disabilities

This type of disability is related to sound impulses, the auditory system or the recording of noise by the brain. Players with this type of disability are especially affected in video games, where much of the gaming experience relies on the sound. According to [40], hearing disabilities are classified as follows:

- Slight/mild hearing loss (26–40 dB).
- Moderate hearing loss (41–60 dB).
- Severe hearing loss (61–80 dB).
- Profound hearing loss (over 81 dB).

This classification can be summarized in two terms: *hard of hearing* and *deaf*. The first term refers to people who have a mild, moderate or severe hearing loss while the second term is used for people with profound hearing loss. Both terms, taken together, represent all cases of people with hearing disabilities [41].

Additionally, there are some initiatives of video games that have incorporated accessibility features for people with hearing disabilities. “MusicPuzzle”, for example, is a video game that encourages active listening among people with hearing disabilities [42]. Moreover, there are video game development companies that include accessibility features in the video games. Her Interactive, for example, is a company that includes subtitles and in some cases subtitled sounds in the video games. They developed the video game “Nancy Drew: Ghost of Thornton Hall” [43] that includes subtitles in all the conversations. This feature allows deaf or hard of hearing people to play the video games more easily.

## 2.4. Cognitive Disabilities

So too, the ICF [37] divides mental functions in global and specific. Global mental functions considers functions such as consciousness, orientation, intellectual, global psychosocial, temperament and personality, energy and drive, sleep and other specified and unspecified. Specific mental functions instead take into accounts the following functions: attention, memory, psychomotor, emotional, perceptual, thought, higher-level cognitive, language, calculation, sequencing complex movements, experience of self and time, and other specified and unspecified.

People with cognitive disabilities usually have difficulty with one or more types of mental tasks than the rest [44]. Mental functions give rise to some cognitive disorders, such as autism, Down syndrome, traumatic brain injury, attention deficit disorder, memory loss dyslexia, dyscalculia and learning disabilities in general.

Furthermore, there are video games with accessibility features for people with cognitive disabilities. “Junk-Food Destroyer”, for example, is a video game that helps adolescents with Down syndrome to understand the importance of healthy eating [45]. Likewise, “Collaborative Puzzle Game” [46] and “MADRIGALE” [47] are video games to foster collaborative skills in children with autism spectrum disorders and to promote phonological training in dyslexic children.

Prior to the design of a video game for people with disabilities, it is important to analyze and understand the characteristics and the different accessibility parameters associated with each disability. In previous works, we analyzed the accessibility parameters for people with visual [48], hearing [49], cognitive [50] and motor [51] disabilities. In this work, we develop an accessible online serious game using all those guidelines previously proposed.

Before explaining the video game design process, it is important to identify some terms that explain the orientation of the online serious game proposed in this work.

## 3. Method and Materials

The method to develop accessible online serious games for people with disabilities starts from requirements definition. The model used for the compilation of requirements and documentation of the online serious game design is the one proposed by Scott Rogers [52]. This model details the way to define all the aspects that comprise and differentiate a video game from any other software and how to design an orderly one.

However, the proposed method in this paper extends the scope of the model used by Rogers to transcend the field of accessibility. The method seeks to incorporate accessibility guidelines with the objective of creating a precedent in the development of serious games and that developers of this type of video games use it as a good practice in each of their software projects. Among the aspects to be described are the general information, the game outline, the characters and objects created, the gameplay mechanic and the video game accessibility, and more.

### 1. General Information

This section contains the general information of the serious game:

- **Game title:** A name for the serious game.
- **Intended game systems:** The platforms on which the serious game could be played (mobile, console, pc, etc.).
- **Systems requirements:** The minimum requirements that are necessary to execute the serious game. This includes the Internet speed connection.
- **Target age of players:** The profile and age of the recommended user for the serious game.

## 2. *Game Outline*

- **Game story summary:** Describe a review of the story that the serious game will tell. It should cover the details necessary to understand the serious game through precise and short wording.
- **Game Flow:** Briefly describe the flow of the game's action in the context of the locations the player will be in. The flow of the game should describe information such as the challenges that will be presented, the rewards for solving challenges, the gameplay in the story and the conditions to win the game.

## 3. *Characters*

At this point, a detailed description of the characteristics of the serious game characters should be made. The following questions can help to define the characters:

- How will the characters look?
- What skills will the characters have?
- How will the characters relate to the story of the game?

The answers to these questions should include all relevant parameters needed for the implementation of the characters in the serious game.

## 4. *Objects*

The serious game could contain several decorative and interactive objects. In this section, it is important to describe each object that the developer will include in the serious game and define its features.

## 5. *Gameplay*

This section should cover details that will be important for readers to understand what technological requirements will be necessary to produce the serious game (hardware and software). Each platform defines its controls and buttons for mobility or functions.

## 6. *Gameplay Mechanics*

According to Rogers [52], it is considered a mechanic to the items or elements with which a player interacts to create objects or help each other to pass challenges.

## 7. *Enemies*

In many video games, enemies are considered the villains who seek to defeat the protagonist of the game so that he does not achieve victory. However, challenges or situations that hinder the advancement or successful end of a video game can also be regarded as enemies.

## 8. *Multiplayer*

The multiplayer feature allows the user to generate teamwork skills and in the educational field it can develop collaborative learning skills. One of the advantages of an online serious game is that the multiplayer feature can transcend borders and generate intercultural ties.

## 9. *Monetization*

This characteristic may change depending on the approach to serious gaming. A large number of online video games are free and profit in other ways such as through advertising. However, there is always the alternative of proposing a serious video game that includes payments for some of its functionalities.

## 10. *Video Game Accessibility*

Accessibility in video games has become a challenge for software developers. Some accessibility guidelines (G) state that serious games should incorporate according to each disability are listed



in Table 1 [53]. It can be seen how each guideline can support one or more groups of disabilities: Visual (V), Motor (M), Cognitive (C) or Hearing (H).

**Table 1.** Accessibility Features.

Guideline	V	M	C	H
G1. Adequate distributed virtual controls	•	•		
G2. Sensitivity sliders		•		
G3. Controls compatible with assistive technology		•		
G4. Adjustable sensitivity/error tolerance	•	•	•	•
G5. Use simple language	•	•	•	•
G6. Voice or text repetition	•	•	•	•
G7. Appropriate words-per-minute				•
G8. Subtitles			•	•
G9. Pause while text is being readed	•	•	•	•
G10. Save Points			•	
G11. Use explicit visual rewards		•	•	•
G12. No timing essential to gameplay		•		
G13. Simple to difficult progression	•	•	•	•
G14. Visual indication of who is currently speaking				•
G15. Controls reminder during gameplay		•		
G16. Simple Controls		•	•	
G17. Challenges repetitions	•	•	•	•
G18. No multiple actions required		•		
G19. No repetitive mechanics.		•		
G20. Easy execution			•	
G21. High Contrast	•			

Note. V: Visual, M: Motor, C: Cognitive, H: Hearing.

Each of these accessibility guidelines are described in more detail below:

- **G1. Adequate distributed virtual controls.** A very useful feature for people with limited mobility and vision. It is recommended that the video game allows for reconfiguring the controls to suit the player's needs. For example, a user who can only use one hand may prefer to bring the controls closer to restrict movement in a smaller area. This feature can make a difference in the experience of a video game.
- **G2. Sensitivity sliders.** There are some disabled players who have little strength, dexterity, mobility or involuntary movements. The ability to set the level of sensitivity allows players to transfer small movements of the controller to large actions on the screen or larger movements on the contrary will lead to more precise game actions. This feature translates into less effort on the part of the player.
- **G3. Controls compatible with assistive technology.** Players with motor disabilities have specific requirements that are commonly translated into the use of specialized hardware. Systems such as flicker detectors, micro-switches that are assigned to buttons or keystrokes/mouse or eye tracking are often used. Adapting to video games for simple movements that can be interpreted by this type of hardware is an important feature to consider.
- **G4. Adjustable sensitivity/error tolerance.** There is no sensitivity level for all video games or players. In addition to personal preferences, some types of players have a restricted range of motion and therefore require very high sensitivity. On the other hand, some players have difficulty with accuracy so they require very little sensitivity and even more so when using alternative input devices.
- **G5. Use simple language.** Using a very specific language may cause the player to not understand the instructions to continue with a video game. For this reason, it is

recommended to use a language that allows one to tell a simple and easy-to-follow story and set aside terms that most players cannot understand.

- **G6. Voice or text repetition.** It is advisable to incorporate the possibility of repeating voice messages or texts within a video game. The repetition feature is used by players when dialogues or texts are difficult to follow.
- **G7. Appropriate words-per-minute.** It is very important to transmit information through subtitles, especially for deaf people. Thus, the number of words per minute must be taken into account—for example, considering the TV industry guidelines [54]. Taking into account an adequate number of words allows players with different disabilities to read the subtitles so that they can fully understand the conversation or instruction.
- **G8. Subtitles.** Subtitles, especially for people with hearing disabilities, have become an essential feature. The incorporation of subtitles in video games allows players to have a more pleasant experience in the history of the video game, as well as allowing them to receive instructions in a clearer way.
- **G9. Pause while text is being read.** In a video game, it is helpful to pause the execution of a text. This feature gives players more time to read the instructions or dialogues of the video game.
- **G10. Save points.** Some video game players may find it difficult to remain seated for long periods of time. This occurs in some cases due to conditions of diseases, such as muscular dystrophy, multiple sclerosis and/or other neurological disorders. For this reason it becomes important to incorporate in the video game Saving Points in order that the player can save his progress and resume it when necessary.
- **G11. Use explicit visual rewards.** People with different learning disabilities require receiving explicit visual or auditory rewards, either for animation or video, as motivation to keep their attention in the video game. This feature will allow the player's skills to increase and motivate them to reach new video game challenges.
- **G12. No timing essential to gameplay.** There are video games in which time requirements are necessary but in others it is not. One recommendation is to avoid time requirements if they are not strictly necessary. This will allow players to enjoy the video game more casually and in a calm manner.
- **G13. Simple-to-difficult progression.** Allow for the modification of degrees of difficulty to a greater extent than usual in games. For example, for real time strategy games, add a speed slider or allow the game to change to a turn mode.
- **G14. Visual indication of who is currently speaking.** Conversations in a video game can be difficult to follow when the player cannot distinguish between different accents and voices. A different color for each character, placing the text on the side of the screen where the character is, naming him or even representing his face, are useful for a person with a disability, so they can recognize the character that is speaking at that moment.
- **G15. Controls reminder during gameplay.** Complex controls can sometimes be difficult for any player to remember and much more for those with memory problems. For this reason, it is helpful that players can access reminders of controls and their specific actions in the development of the history of the video game.
- **G16. Simple controls.** The controls are simple and quite intuitive. Even the default control settings should follow how most games work, so people with experience in video games will find it even easier.
- **G17. Challenges repetitions.** On many occasions the players do not have enough ability to overcome the different challenges of video games. This occurs more frequently in the case of people with disabilities. For this reason it is important to allow the challenges to be repeated countless times or at least the video game should enable this option to be activated.



The challenges do not require extreme accuracy in order to be overcome by the players and, if they fail, they can be repeated.

- **G18. No multiple actions required.** Players with motor disabilities often have difficulty pressing the controls of a video game. For this reason it is important to avoid executing several actions that involve pressing several buttons at the same time. In the case of the video game, the player must only advance and jump at the same time for certain obstacles, but no challenge should require the user to press more than two buttons at the same time.
- **G19. No repetitive mechanics.** For many players, especially those with motor disabilities, it is often complex to perform repetitive actions during the development of the video game. Thus, it is recommended to avoid the use of repetitive mechanics such as pressing quickly and many times a button.
- **G20. Easy execution.** Young children and people with cognitive disabilities often have problems in video games in which many configurations or steps are required to start playing. For this reason it is important that the start of a video game is as simple as possible avoiding navigation through multiple menus.
- **G21. High contrast.** People with low vision commonly have trouble appreciating the scenes of a video game. It is for this reason that the ability to alter the contrast and other graphic features of the video game, such as lighting, may be helpful for the scenes to be displayed more clearly for the player.

#### 4. Case Study

Once the method of developing online serious games has been described, its application is presented in a case study oriented to learning the architecture of a computer. The online serious game will be tested by a group of users and the results obtained will be discussed.

##### 4.1. Development

Nowadays, applications to develop video games are accessible to the common user and there are several available in the market [55]. This has allowed the common player to get involved in the field of video game developers. Among these tools is the Roblox application which has shown great growth in recent years [56]. Roblox is an online and free platform that allows users to create their own games or play those created by other players. Additionally, Roblox is cross platform. This feature allows it to be run on any type of device: smart devices, video game consoles, personal computers and more. Another interesting feature of Roblox is its ability to host video games in three dimensions. The player can customize the game to his/her liking and has access to a varied collection of objects [57].

In this section, we apply the proposed method in a case study of an online serious game that encourage players to learn about computer architecture.

##### 1. General Information

- **Game title:** PC TRAVEL.
- **Intended game systems:** Roblox platform allows the following systems:
  - Android OS from version 4.0.3 onwards.
  - iOS from version 8 onwards.
  - Amazon Fire OS, 3rd generation onwards, except Amazon Fire HD 2013.
  - PC from Windows XP OS onwards.
  - MAC from version 10.7(Lion) onwards.
  - Chrome OS from version 53 onwards.

It is important to indicate that Roblox is compatible with virtual reality systems, such as Oculus Rift and HTC Vive.

- **Systems requirements:** The minimum requirements that a computer requires to run Roblox are:
  - Graphics card that supports DirectX 9 and Shader Model 2.0.
  - Recent processor, released in 2005 or later, with a speed of 1.6GHz or better
  - 1 GB of RAM minimum
  - 10 MB of storage space at least

Finally, the required Internet speed is a minimum of 4-8 Mbps for the connection and also 3G or higher networks in the case of mobile devices.

- **Target age of players:** The online serious game is recommended for 6-year-old individuals and those that are older. The game is educational and informative, so it has a large amount of text since the information given is based on dialogues. For this reason it is recommended that the player knows the English language for a better experience.

## 2. Game Outline

- **Game story summary:** The game is developed inside a computer and it has several elements corresponding to the architecture of a computer. In each element there are some characters called “helpers” that share information with the player. The player must go through the different elements of the computer solving challenges and answering questions that evaluate the knowledge that is acquired in the online serious game. Figure 1 shows a screen of the online serious game outline.

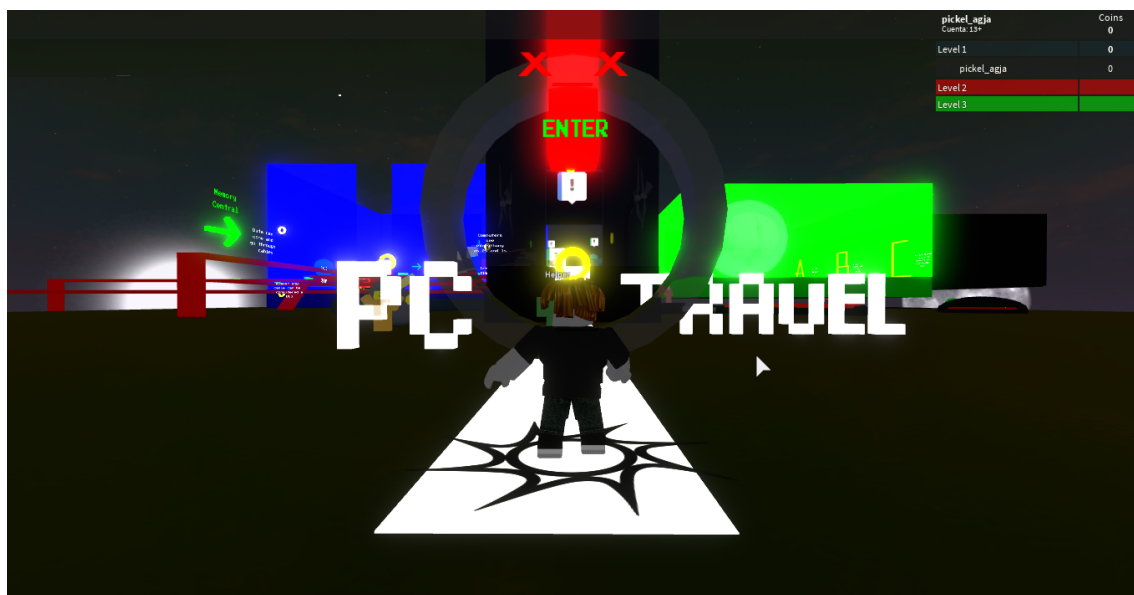
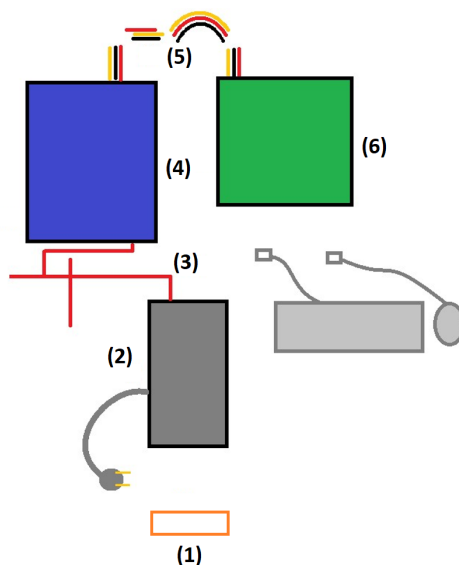


Figure 1. PC TRAVEL Initial Screen.

- **Game Flow:** Figure 2 represents a map detailing the stages and order of the route that will be applied to the game:



**Figure 2.** Serious Game Map and Stages: (1) Start (2) PC Chassis (3) BUS (4) Memory Center (5) Connector Bridge (6) Processing Center.

Next, we will describe the script that will follow according to what is shown on this map.

- 1 **Start:** This is the point where the player initially appears in the online serious game world. Information is presented oriented to the instructions to be followed by the player. It is an open space without challenges yet, so that the user can perform a recognition of the controls and the environment of the online serious game.
- 2 **PC Chassis:** This element represents a computer chassis. The first signs of the game direct the player to this element. Within this block, information about the fans and their importance for cooling the computer is presented. Additionally, a brief introduction is given to the next area the player will enter.
- 3 **BUS:** On the back side of the chassis, there is a Serial Advanced Technology Attachment (SATA) cable connection where the player must move. Information is presented about buses and how the bits travel inside a computer. The player must jump between cables that take him to different directions. The player must collect all the coins to reach the memory center. At this point the first challenge is presented: to explore and discover all the coins and avoiding falling off the buses in order to reach the next element.
- 4 **Memory Center:** In the entry of this element, a “helper” evaluates the player with a question. If the player answers correctly and has also collected all the required coins, the door for the next stage will be opened. In this block, there are 3D models of the following types of memories: Read-Only Memory (ROM), Random Access Memory (RAM) and a secondary memory (a hard disk). There are several types of challenges incorporated in this block: elements that vanish, balance challenge, hidden locks, among others.
- 5 **Connector Bridge:** This block corresponds to a 24-pin power cable/connector. The challenge is to jump between cable segments and avoid falling into the void. The bridge is not completely built. The player must correctly answer a series of questions so that new segments of the bridge are discovered. Additionally, if the player answers a question incorrectly, the segment in which the player is standing will disappear and fall into the void.

- 6 **Processing Center:** This block has a large brain that represents the control unit. There is also an Arithmetic Logic Unit (ALU) represented with a calculator that teaches the basic operations of the machine binary language: AND (sum) and OR (multiplication). In this block there are a series of challenges related to all the elements reviewed in the game. If they are answered properly, the game is over, otherwise the player will return to a previously saved point.

### 3. Characters

A main character has not been designed in the online serious game. Roblox defines the character for each user independently. PC TRAVEL presents two types of characters with which the user interacts:

- **Helpers:** They are friendly looking characters. The player interacts with them through dialogues that vary in their presentation depending on the type of conversation. They have an identifier on their head, so that the player can know their role in the game is to give varied information and help, as we can see in Figure 3. For example, a Helper with a “!” sign gives the player important information about concepts and definitions that will be useful to resolve the challenges. On the other hand, a Helper with a “?” sign ask the player questions about the concepts learned in order to complete the challenges and continue with the online serious game.



Figure 3. Examples of “Helpers” in PC TRAVEL.

- **Brain:** The player interacts with this character through a text dialogue. The Brain dialogue is more formal than a helper since this character must be presented more cold, imposing and calculating. Brain, represented in Figure 4 is the representation of the control unit, who directs and manages all processes within a computer.

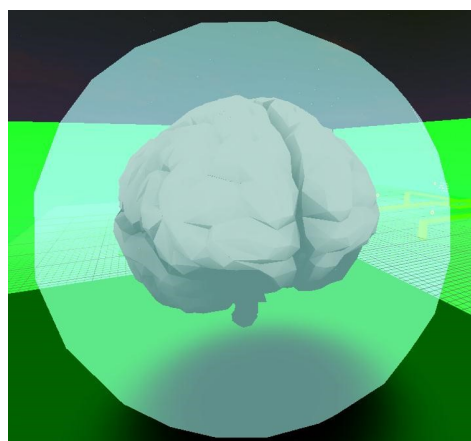


Figure 4. Brain character representation.

#### 4. Objects

The online serious game contains several decorative and interactive objects. Next, those that have some kind of interaction with the player are described:

- **Coins:** They are elements that the player must collect throughout the game. All collected coins accumulate in a total score. The presence of a coin implies important information for the player.
- **Interactive Doors:** There are two types of interactive doors in the serious game. The first one opens when the player correctly answers one of the questions posed by the helper. On the other hand, the second door opens or closes depending on whether a button is kept pressed or not.
- **Interactive Stairs:** There are two types of interactive stairs in the online serious game. The first are a system of blocks that appear and disappear in a simple sequence that the player must synchronize with the jumps in order to reach the other end. The second are segments of a bridge that appear when a question is correctly answered. If the player on the other hand responds badly, the block on which the character is standing disappears leaving them to fall into the void.
- **Interactive Platforms:** The three interactive platforms are in the last block. They are part of a challenge where the player must answer some questions. If the player answers correctly, it will turn green and the game will end. If the answer is wrong, a door in the platform will turn red and then drop the player to the void to repeat the section.
- **Checkpoints:** These are the automatic save points where the player reappears in case of losing all their life points and die figuratively in the online serious game as we can see in Figure 5.



Figure 5. Saving Checkpoints in PC TRAVEL.

- **Serious Game World:** The design of the online serious game was based on the command interfaces of the computers. There are dark backgrounds and the contrast of elements such as buildings or characters in neon primary colors. This is recommended in order to obtain a high contrast environment that facilitates the accessibility of people with visual impairments. From the square design of all the elements to the words are selected on purpose to give a modern and technological environment to the online serious game, as we can see in Figure 6.

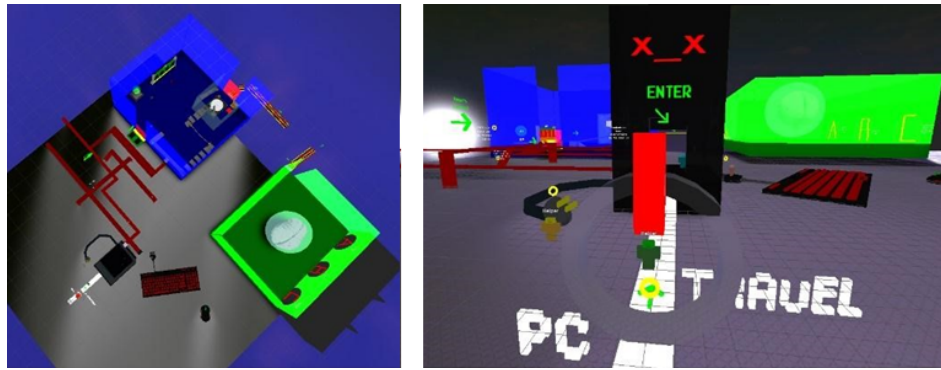


Figure 6. Top and front view of the serious game world.

In this way, it is intended to make it easy for the user to immerse themselves in the online serious game world and experience a very close sensation to being inside of a computer.

#### 5. *Gameplay*

Roblox provides the gameplay in the different platforms in which the online serious game can be executed: mobile devices (Android, iOS), computers and video game consoles. On each platform, the controls are defined for each action required by the player, for example:

- Mobility button: forward, back, left, right.
- Functions buttons: jump, hit, shoot, run, etc.
- Menu button: to access the options.

In addition to the predefined options, a developer can add extra buttons on the screen to activate more features that the video game requires.

#### 6. *Gameplay Mechanics*

In the case of people with motor disabilities, the interaction becomes more complex due to their condition. For this reason, some accessibility features are recommended for them, such as: sensitivity, speed, and repetition controls, among others. On the other hand, the dangers or obstacles are those elements without their own intelligence that threaten to hurt or kill the player. The main mechanics in this online serious game are listed below:

- Interact through dialogues in search of information and answer questions.
- Collect coins in the online serious game to give the incentive a reward to the player.
- Jump to overcome obstacles by measuring distances and times in which it is done.

#### 7. *Enemies*

There are no bosses or enemies within the online serious game that the player must kill or defeat. The online serious game is intended to be educational and, above all, even about entertainment, it is intended that the user can learn about the interior architecture of a computer at his own pace. The use of enemies for obstacles was not implemented because the story developed within the online serious game does not need antagonists either.

However, throughout this online serious game, there are multiple challenges to be overcome by the player. The stands, bridges and questions could be considered as enemies since threats are possible for the player. They can waste the time or the player life points, and this is what makes them qualify as a type of enemy.

#### 8. *Multiplayer*



This online serious game is for a single player, but several can play it at the same time, each in an iteration created instantly by the Roblox client. A player will never meet another during the development of the game.

In this online serious game, teamwork was not considered as an objective because it is not what we intended to teach. The learning experience of it is more individual, so that each user can go at their own pace. Speed is not important, but that the player truly receives and retains the information given.

#### 9. Monetization

The online serious game is free and available to anyone who downloads it from the official website. This project does not seek an economic remuneration since it is a prototype that encourages the creation of more video games of this type following the idea already raised, either in the same video game engine or another more powerful one that allows to cover much more of the subject, with more challenges, mechanics and content.

#### 10. Video Game Accessibility

Roblox, as an engine for developing video games, includes certain accessibility features natively. This is the case of the G1, G2, G3, G4, G6, G7, G9, G11, G12, G13, G15, G16, G19, G20 guidelines. In Figure 7, for example, the adequate distributed virtual controls and the simple controls guidelines are present on the left screen and the sensitive sliders and error tolerance guidelines are present on the right screen.



**Figure 7.** G1. Adequate Distributed Virtual Controls and G16. Simple Controls—(Left): G2. Sensitive Sliders and G4. (Right): Error Tolerance.

As shown in Table 1 above, through those specific features, PC TRAVEL attends various types of disabilities. Furthermore, of all the features included by Roblox, the following have been implemented in the online serious game:

- **G5. Use simple language.** This guideline is represented in Figure 8 (Left). As we can see, the texts used do not contain a very technical language and difficult to assimilate in such a way that the player can understand it without problems.
- **G8. Subtitles.** In Figure 8 (Left), we can see the subtitles feature for the video game.



Figure 8. Subtitles and Use of Simple Language (Left) and Save Point (Right) examples.

- **G10. Save points.** In Figure 8 (Right), an example of the use of save points is presented. The user stands on the black mark and the game progression will be saved.
- **G14. Visual indication of who is currently speaking.** In Figure 9 (Left) we can see this feature in the video game.
- **G17. Challenges repetitions.** Figure 9 (Right) presents one of the challenges of the video game. The player must jump through steps that appear and disappear from time to time and in sequence. This is a challenge that allows the player to make mistakes and try again as many times as he needs.



Figure 9. Example of “Who is currently speaking” (Left) and Video Game Challenge (Right).

- **G18. No multiple actions required.** In the case of the video game, the player must only advance and jump at the same time for certain obstacles, but no challenge requires the user to press more than two buttons at the same time.
- **G21. High Contrast.** In the Figure 10, one can see the elements with which the player must interact, which have a neon color. Shiny coins, for example, are easy to place visually for their neon glow.



Figure 10. High contrast example between components in the video game.

#### 4.2. Results

The online serious game was developed using the proposed method in order to support the learning process of people that want to know more about computer architecture. Another important feature is that the online serious game intends to decrease the existing gap for people with disabilities who tries video games to entertain or learn. As seen from our results, the proposed method considers the necessities edges for the construction of an online serious game without neglecting the accessibility characteristics for people with disabilities. An important feature that was validated about the proposed online serious game refers to the ease of running on different platforms: mobile, computer, tablet and play station. This feature makes it possible to cover a larger number of users and even take advantage of the benefits, including accessibility, of the different devices.

In order to analyze the usability that the present online serious game proposes, a sample of ten people without disabilities was taken to play the online serious game. Later, a survey was realized to collect information that allows us to analyze the impact of the online serious game in the group of users.

The first questions of the survey were aimed at knowing the backgrounds of users' knowledge. In this information it was possible to know that 90% of the users were interested in topics related to computers and video games. Subsequently, an analysis was made of the start and end time that the users delayed in playing the game. On average, users took 27 min and 6 s to finish the game. The results are presented in Table 2.

Table 2. Serious game resolution times per user.

User	Session Start	Session Finish	Total
U1	11:55	12:34	0:39
U2	15:45	16:35	0:50
U3	17:41	18:00	0:19
U4	19:00	19:16	0:16
U5	19:00	19:20	0:20
U6	20:50	21:15	0:25
U7	22:13	22:30	0:17
U8	21:10	21:32	0:22
U9	22:24	23:15	0:51
U10	22:37	23:00	0:23

On the other hand, once the users played the online serious game a set of questions was asked to obtain more information. The 60% of the users considered that, after playing the game, they increased their knowledge and interest in computers. Additionally, at the time of asking the users about their perception of the difficulty of the online serious game, 60% think that it has an intermediate level of complexity and above all 70% respond that it seems appropriate to reinforce the classes with playful tools such as serious games.

## 5. Discussion

In this study, we proposed a method for developing online serious games for people with disabilities. The method takes into account criteria and parameters from the technical to pedagogical field. The method extends its application to a field that is not yet strong and explored enough, accessibility for people with disabilities.

Likewise, we examined the alternative of an online serious game approach as a teaching tool for people that want to learn about a computer architecture. Some studies reveals that the use of video games in education is a valid and useful strategy for teaching [58,59]. Results of the present study suggest that online serious game motivates the users to use alternative tools for learning.

Taking into account the results obtained in the users surveyed, it can be determined that the video game fulfills its objective as serious game of informing and encouraging them to learn more about computers to those who play it. Additionally, after the application of the survey, we discovered some aspects that should be improved. For example, several players indicate that it is necessary to include a greater number of devices and computer peripherals such as printers, scanners, mice, among others. It is important to consider criteria to improve the design and content of the online serious game.

Additionally, despite the fact that 60% of people considered an increase in their knowledge using the online serious game, this percentage is relatively low. It could be the situation that several of the users who participated in the tests had prior knowledge about computers. Another alternative could be that the topics taught mostly addressed generalities and that the target audience for the use of the proposed online serious game should be another. The relevant fact is that serious games contribute to teaching in a didactic way.

Something important about the survey is that users recommends the online serious game to be a part of an informatics course considering that it could be aligned to the learning outcomes of a professional in this field. This is leveraged with the 70% of respondents who think it would be appropriate to reinforce classes in different subjects with this type of teaching strategies through serious games. This could be an opportunity to improve the serious game reinforcing educational and pedagogical methods, taking into account the age of the potential users.

Even recent studies recommend parents and caregivers to use serious games to improve social cognition of young children, including those with some kind of disability, during the Coronavirus (COVID-19) stay at home period [60]. These studies indicate that serious games could be an educational alternative to video games or the internet tout-court.

On the other hand, accessibility features were attractive for users considering that all of them can improve the experience of people with impairments. These characteristics help people with special conditions to enjoy the serious game and more important to assimilate the proposed knowledge.

## 6. Conclusions

This paper deals with the relation between a method to develop online serious games with accessibility features and the teaching process. The study case is about PC Travel, an online serious game to support the computers architecture learning. This initiative contributes to the education of people with disabilities. The use of accessible serious games supports the Article 24—Education of the United Nations Convention on the Rights of Persons with Disabilities [21], considering that it supports people with disabilities to have access to education on equal terms with a person without disabilities. Likewise, the current pandemic generated by COVID-19 has caused the closure of schools and the

growth of online learning from home. In these situations, the existence of supports, such as serious games, becomes an essential element to face the limitation of attending schools in person and having the physical accompaniment of the teacher.

It is important to take into account that a larger and more varied sample of users needs to be tested. This will allow us to obtain more concrete results regarding the objectives that the online serious game wants to achieve. The proposed online serious game could be used to generate a greater interest in the elements of a computer and its operation, in users that are not related to computer science area.

The Roblox platform facilitates, in many aspects, the development of video games like that presented in this paper. However, this platform is still too limited to be used for a final implementation of this idea. For example, the graphics are still very simple and it is not possible to give real detail about the components. In more advanced video game engines, the same idea could be implemented, but with scale models, including the internal components of a computer and more accessibility guidelines.

Serious games are a strategy to present a seemingly serious theme, such as learning in a fun and playful scheme. The average time to complete the game is relatively short. This is adequate because it is intended that the online serious game in the future can be used as a training method in offices or other sites to learn about assembly of computers and its operation. It would not be viable or practical for the game to take an hour to complete or more. This would affect the productivity of employees who mainly have to attend their functions in an office.

Software accessibility should not be neglected. In fact, although there are accessibility standards, for the web specially, a specific standard for video games has not yet been defined. The implementation of accessibility features in the software sometimes implies that its design and implementation take more time taking into account that several accessibility features are complex to implement.

In the future, we will extend the game to include more features of computers and new smart devices. We will also try to study the long-term effect of playing the game regularly in an education and office environment. Additionally, we will work toward incorporating a multiplayer mode in order to develop collaborative learning and teamwork capabilities in the player. Additionally, an accessibility analysis of the video game development platforms is planned. Finally, we will include more accessibility features to broaden the spectrum of people who can use this online serious game and in this way reduce the entertainment and learning gap that they may have.

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## Abbreviations

The following abbreviations are used in this manuscript:

ICT	Information and Communication Technologies
APX	Accessible Player Experiences Patterns
WHO	World Health Organization
ICF	International Classification of Functioning
ROM	Read-Only Memory
RAM	Random Access Memory
ALU	Arithmetic Logic Unit
UN	United Nations

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