Appendix C

Design Considerations

C.1 Design Principles

There are many articles covering tools and strategies to support the process of designing games for learning. Kiili et al (2012), for example, describes a series of design principles to achieve the state of flow (Csikszentmihalyi, 1991) during the intervention: clear goals, immediate feedback, sense of control, and playability. Furthermore, an increasing level of challenge can lead the user to focus on a rewarding experience in which he or she loses a degree of self-awareness and feels a temporary distortion. This type of experience, to the extent that the user maintains a significant cognitive load through the challenge, produces the mental effort that may lead to learning (Mayer, 2014).

As the central design axis, the theoretical framework proposed by Plass et al. (2015) was chosen. The framework proposes a flexible structure that can be applied to any game-based learning design process. It is articulated in a concept map whose dimensions can support the necessary scaffolding for game-based learning. The base level in this scheme is the INTERACT model (Domagk et al., 2010), where four main dimensions are articulated: 1) affective engagement; 2) behavioural engagement; 3) cognitive engagement, 4) and socio-cultural engagement. Achieving engagement in these four dimensions is one of the main objectives of the design so that the game must guarantee a complete experience aligned with the required learning (Plass et al., 2015). These four provided dimensions serve as reference points to find weaknesses in the system design and the interaction it proposes to students. As a way to regulate these dimensions in the user's relationship with the system, Plass et al. (2015) proposes that the following fundamentals be articulated from the design: 1) cognitive foundations; 2) motivational foundations; 3) affective foundations and; 4) socio-cultural foundations. As a tangible example of this, the authors propose seven dimensions that the game design must include to achieve a ludic learning experience.

C.1.1 Content and Skill

In this case, the game is not designed to teach a specific curricular content but instead to develop CPS as a skill. The use of roles for each player was prioritized for the design of the collaborative game (Nussbaum et al., 2009; Seif El-Nasr et al., 2010). The rules governing the system were then articulated based on these roles (See section C.2, Appendix C). These roles are assigned to each player according to the order in which they connect to the system. They are complementary roles that can form different types of relationship with the game environment depending on the team's interdependent interactions. These roles allow users to formulate different hypotheses and strategies for solving problems according to the characteristics of each character and the tasks within the game.

To ensure that our task was collaborative, we met the conditions established by previous studies (Szewkis et al., 2011): a common team goal was maintained (Dillenbourg, 1999; Seif El-Nasr et al., 2010); the puzzles were based on positive peer interdependence (Johnson & Johnson, 1999) and coordination and communication between them (Gutwin & Greenberg, 2004); the responsibilities of each player within the team were defined (Slavin, 1996); evidence of the rest of the team's actions was included in order to ensure there was group awareness (Janssen et al., 2007); the reward system, although minimal, was always collective (Axelrod & Hamilton, 1981); and all restrictions, such as health and energy, were shared by the team (Seif El-Nasr et al., 2010).

C.1.2 Incentive system

In this sense, when designing the game's incentive system, a distinction was made between the proposed Digital Game-Based Learning application and a gamification system. The latter focuses on using incentive systems to encourage and guide users towards a specific behavior with extrinsic motivation (Hawlitschek & Joeckel, 2017). In this case, rewards are external to the game and given when the user demonstrates the required learning dynamics. Collaboration should therefore be driven by a desire to play, explore and solve the game with peers, rather than a reward that does not contribute towards this goal. When designing this system, we opted for mainly internal incentives so that the difficulty of the task would help motivate users to develop more effective collaborative strategies in order to solve it. In this sense, the game

only includes an experience point system, in which players accumulate points as they advance and solve puzzles within the game. However, these points cannot be used for anything inside the game and do not lead to any prizes for the students.

C.1.3 Learning mechanics

Appendix D, together with Appendix E, give a detailed explanation of the evolution of tasks during the game. The design includes the use of complex scaffolding and soft scaffolding (Chen & Law, 2016), including text messages that seek to guide the students in order to recognize the forms of interaction that are available to them. On the other hand, the logic of graceful failure was also incorporated (Juul, 2013), in which any mistake made by a player can easily be amended or, at least, would not be serious enough to make the player give up too soon. In this sense, the health and energy system described in Appendix C is has a long duration and is easy to recharge. The system therefore avoids frustration becoming a barrier to learning, while also not being overly simple and negatively affecting the cognitive learning process (Kiili et al., 2012).

C.1.4 Assessment mechanics

The assessment mechanics within the game are based on the increasingly interdependent interactions that the team must have in order to progress. The team's success or failure at a task is recorded in a log. To ensure the tasks are clear and so as to avoid any unnecessary confusion, the game includes a feedback system based on a character who gives information in the form of a dialogue. We therefore use a cross-delivery feedback system between students in order to foster interaction based on the skills required by each task. In this sense, the Green player receives information that is relevant for the Red and/or Yellow player, the Red player receives information that is relevant for the Green and/or Yellow player, and the Yellow player receives information that is relevant for the Green and/or Red player.

C.1.5 Aesthetic design

The game interface (See Figure C.1) is detailed in Appendix C. It was designed to emulate standard controls on modern consoles and to allow clear interaction for students. The game was designed so that the three players can interact with each other via oral and kinesthetic speech freely throughout the experience. In early prototypes, we could see that users were not able to express their ideas or organize the team effectively through text-based chat alone. Using the keyboard on the tablets was not a fluid process; it could not keep up with the rhythm of interaction offered by the system, leading to general frustration at the somewhat uncomfortable and unusable mechanism.

C.1.6 Narrative design

The narrative looked for the players to co-create their own story. In this sense, the system does not include a single, particular narrative. Instead, it shows or reveals a series of images, to which the group can then attach a meaning or emotion, based on whatever they co-construct (Maine, 2017). The feedback provided by the game and the little dialogue that is included all reference aspects of collaborative problem solving, such as the difficulties that can be faced when solving collaborative problems, as well as its value in everyday life.

C.1.7 Musical Score

Finally, the music consisted of 6 open source songs from the chiptune album called "Music for an Unmade Forest World" by the artist Visager (2017), taken from the Free Music Archive (2018). Sound effects for the players' actions were also included.

C.2 Roles

There are three roles that players can assume when they enter the game (Table C.1). For neutrality, we summarise them into three names: 'Green', 'Red', and 'Yellow'. Each of these avatars has a unique ability to interact with the environment.

The primary consideration to define the roles was through a special ability system. Each player pressed the B button to start consuming energy. This action triggered a change where the player acquired a new ability. Different types of aura and sound were activated to represent this to each player. Through this new ability, we figured out what Rocha et al. (2008) suggested.

Table C.1

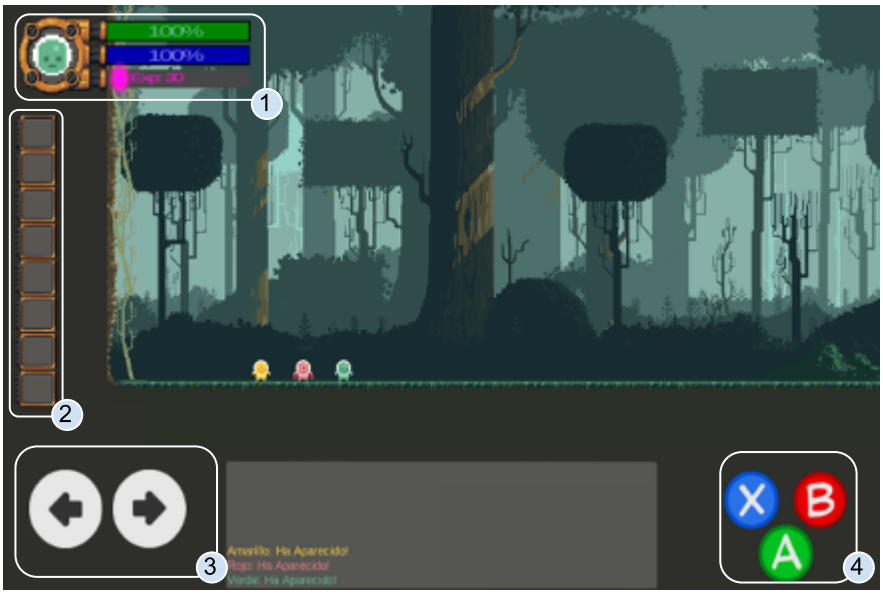
Game roles

Avatar	Ability	Display
Green	Protect players within the energy field.	
Red	Destroy and move heavy objects.	
Yellow	Increased speed and double jump.	

C.3 Basic Actions and Interface

There are six basic actions in the game: move horizontally, jump, shoot, activate/deactivate special ability, recover health and energy, and use basic items. These six actions are common to all three users and are represented through the game interface in Figure C.1.

Figure C.1
Game Interface



At the top left of the screen (Section 1, Figure C.1), to avoid confusion and recognise one's role, the system shows the player which avatar corresponds to him/her. Besides, health and energy indicators can be seen, as well as experience level. The team shares these statistics during the game, i.e., everyone is dependent on the same energy and health supply. To renew energy and recover their health, players must approach fountains that are scattered throughout the game.

At the lower left (Section 2, Figure C.1) is the found items inventory. The items are displayes that the players were able to collect to use later within the game. The items do not change the form of interaction, but they are helpful to open doors (among others) within the game, for example.

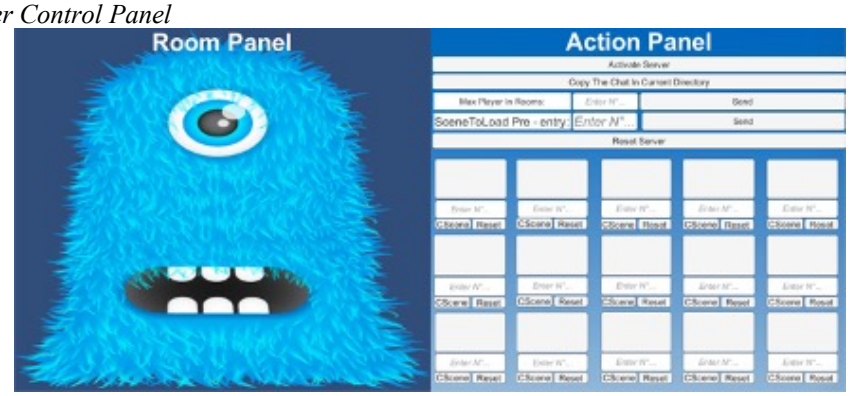
At the lower-left corner (Section 3, Figure C.1), there are the horizontal scrolling arrows. At the bottom centre is a log where the players receive relevant information about the game; for now, it only summarises the connection and disconnection of their teammates from the game.

Finally, the game's basic interaction buttons are at the bottom right (Section 4, Figure C.1). The B button is to shoot the opponent the player faces in a horizontal direction, the A button is to jump, and the X button activates the special ability of each player's role. The tutorial ensures that players fully understand these dynamics.

C.4 Server Interface

Figure C.2

Interface Server Control Panel



The interface is managed by the teacher or operator (Figure C.2) and consists of two sections grouped on the right side of the screen. The first one is to activate the server (start the game), enter the number of players, and the stage at which each game room will start.

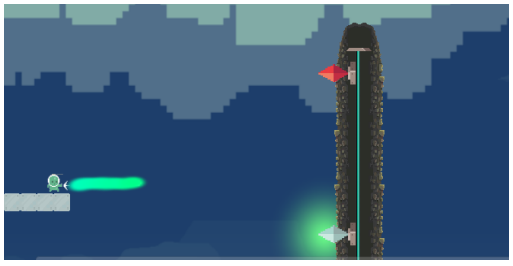
In the second section, there are fifteen boxes. In these, the operator can monitor that the players enter the game correctly. Each of these units can be manipulated by the teacher. The system can: 1) restart the level; 2) Send players to their last checkpoint; and 3) change the players' stage. This section is helpful in case of problems with the game or if teachers want to move a team from one stage to another for a particular reason.

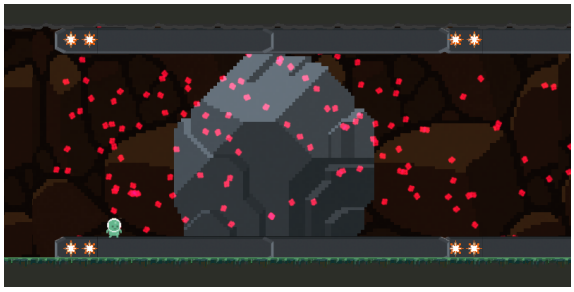
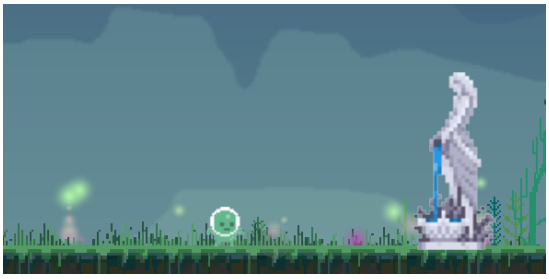
C.5 Collaborative Interactions

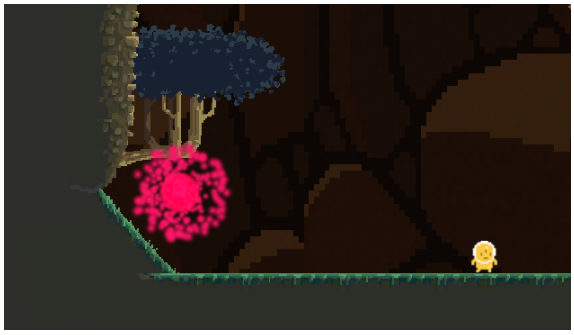
Interdependence plays a fundamental role in understanding the task outlined in the PISA framework (OECD, 2017). Therefore, the game consists of a set of basic rules and interactions to generate puzzles that include the skills of each role. As a result of this principle, the following seven systems have been generated (Table C.2).

Table C.2

Basic collaborative interactions.

Floor Switch	Button on which the player must be positioned to activate. They can be individual or group, synchronous or diachronic, and assignable to each role or a generic purple switch.	
Switch Shot	Switches activated by the respective player's shoot. It has permanent and temporary activation modes in need of special ability activated or without. They can be for a specific player or generic.	

Altar	In the game, there are platforms called "Altars". These players can transport their skill to another demarcated area of the map. This altar allows players to share their skills in remote areas. The green player activates a protected area; the red player an area where whoever fires will do so with projectiles borrowed from his role; the yellow player transmits a change in gravity.	
Shared Skill Zone	The recently mentioned altars activate areas like this. These areas can be activated from a distance via altars or switches and can also be activated simply by contact with the right player. The colour of the stars on the edges defines the role that activates the areC.	
Health and Energy recovery.	There are water fountains scattered throughout the game. When players approach these fountains, they begin to recover health and energy. For each player approaches, the regeneration frequency increases.	

Teleporter Player	Fucsia coloured portals that, after contact with a player, transport it to a default areC.	
Teleporter Shot	By shooting at these portals, players will be able to teleport their shots to other locations. In this way, players can intervene in another player's zone under their signal.	
Destructible obstacles	Some obstacles can only be destroyed or displaced with the special 'Red' ability. Within these items, some disappear forever, and some are temporarily disabled only to encourage and strengthen players' ability to coordinate.