PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
SCHOOL OF ENGINEERING

DESIGN GUIDELINES FOR A CLASSROOM MULTIPLAYER PRESENTIAL GAME

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Thesis submitted to the Office of Research and Graduate Studies
in partial fulfillment of the requirements for the degree of
Master of Science in Engineering

Advisor:
MIGUEL NUSSBAUM

Santiago de Chile, November 2011

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Gratefully to my family

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ABSTRACT

The video game industry is constantly growing in the market. Their capacity of entertainment provokes high levels of immersion that are not usually found at a traditional classroom activity. Diverse experiments have tried to use these capacities in the classroom without achieving the proper levels of integration. All design elements must be considered to build an educative classroom videogame. Our proposal consists in defining the design rules that must be considered at the time of designing a CMPG (Classroom Multiplayer Presential Game). Existent bibliographic revision was considered and a field study was taken using a CMPG. The field study contemplates 40 students playing the game measuring their curricular performance, rules effectiveness and players motivation. The results show how a Design Guideline improves the effectiveness when designing a CMPG.

Keywords: Classroom Multiplayer Presential Game, Game design guidelines, Collaborative game, Learning in the classroom, Educational game

RESUMEN

La industria de los videojuegos se encuentra en constante crecimiento en el mercado. La capacidad de entretenimiento de estos puede provocar grandes niveles de inmersión, que muchas veces no se encuentran en la sala de clases. Se han realizado diversos experimentos para intentar llevar estas capacidades a la sala de clases sin lograr niveles de integración adecuados. Para realizar esta tarea con éxito es necesario contemplar los elementos de diseño de un videojuego educativo en la sala de clases. Nuestra propuesta consiste en definir reglas de diseño que deben ser consideradas al momento de diseñar un CMPG (Classroom Multiplayer Presential Games). Para esto se utilizó la revisión bibliográfica existente y se realizaron pruebas de un CMPG en terreno. La prueba se realizó sobre 40 alumnos a los cuáles se les midió su desempeño curricular, correcta utilización de las reglas y motivación al jugar. Los resultados demuestran que la utilización de la guía de diseño incrementa las posibilidades de efectividad al diseñar un CMPG.

Palabras Claves: Juegos Colaborativos Presenciales, reglas de diseño en juegos, juegos colaborativos, aprendizaje en la sala de clases, juegos educativos.

1. INTRODUCTION

1.1. Motivation

> Since the widespread popularity of Pac-Man in the early 1980s, some educators have wondered if the magic of Pac-Man cannot be bottled and unleashed in the classroom to enhance student involvement, enjoyment, and commitment. (Bowman, 1982).

Three decades have passed and the classroom remains the same traditional way. Students are passive recipients of the material prepared by the teacher. There is no space for students to learn through experience.

Collaborative Learning (CL) goal is to assist the teaching of a specific curricular content through coordinated and shared activities, by means of social interactions among the group members (Dillenbourg, 1999). Computer Supported Collaborative Learning (CSCL) aims to support CL by using technology within the classroom. Although CSCL achieves supporting CL (Zurita & Nussbaum, 2004), it left a side playfulness in most of their applications.

On the other hand video games have captivated millions of players. World of Warcraft (WoW) is a Massive Multiplayer Online Role Playing Game (MMORPG), in which players from around the world assume the roles of heroic fantasy characters and explore a virtual world full of mystery, magic, and endless adventure (Blizzard, 2011). World of Warcraft counts with more than 12 million active players, more than Cuba or New York 's population. Figure 1.1 shows a World of Warcraft scene.

FIGURE 1.1. World of Warcraft.

MMORPGs are characterized by (Susaeta, H, Jimenez, F., Nussbaum, M, Gajardo, I, Andreu, J, & Villalta, M, 2010):

- Fantasy Enviroment that favors immersion and flow. (Csikszentmihalyi, 1990)
- The interactivity with the virtual world and peers through the virtual world.
- History and structured scripts.
- Challenges and missions that develop critical thought, teamwork, and problem-solving strategies (Dickey, 2007).

The essential contribution of MMORPGs to interactive learning environments is thus their support of intrinsic motivation (Susaeta, H, Jimenez, F., Nussbaum, M, Gajardo, I, Andreu, J, & Villalta, M, 2010) and serves as a platform for Collaborative Activities. When we consider its use in school, Bbecause the players are inside the classroom, we replaced the word *Massive* for *Classroom*, and because they are all present in the same physical space, interacting presentially, we substituted *Online* for *Presential*, thus obtaining Classroom Multiplayer Presential Game (CMPG), where there is a link between the mechanics of the game and the teaching process. Just as in MMORPGs there is a game master, in CMPG; the teacher plays the role of game mediator, with the educational contents laid out in the virtual world, as well as in the direct interaction amongst students. Figure 2.1 shows a CMPG in action.

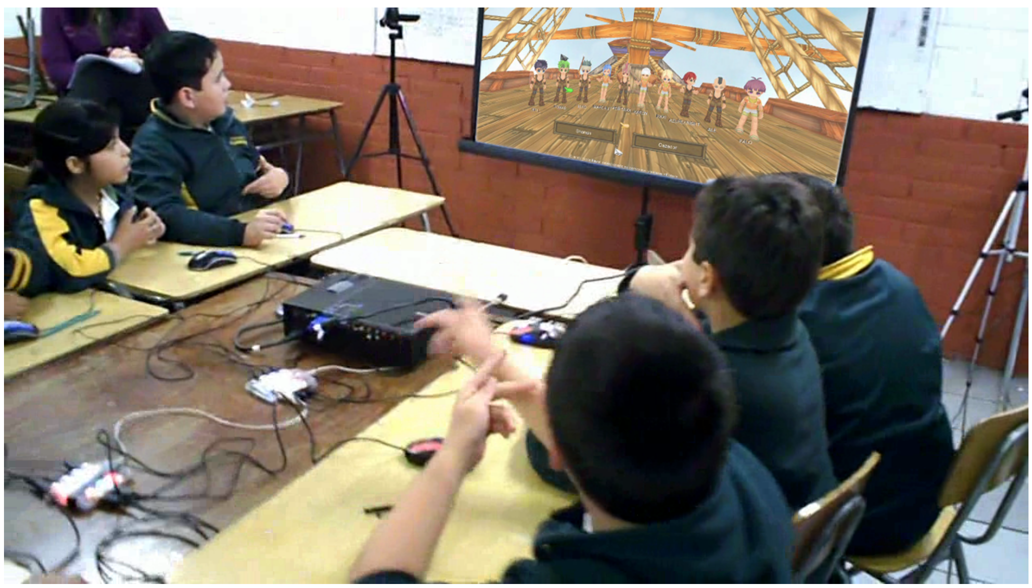

FIGURE 1.2. CMPG.

With this approach we intend to develop and systematize guidelines for the design of CMPGs that support teaching activities linked to curriculum contents in the classroom. While using these guidelines in the design process of a CMPG we expect that the synergic relationship between education and entertainment comes around in natural way

My thesis work is to design and implement the game Osos 2. Osos 2 is game to teach ecology for students. A previous version, of Osos, was made in (Susaeta, H, Jimenez, F., Nussbaum, M, Gajardo, I, Andreu, J, & Villalta, M, 2010) which intended to explore the use of MMORPG in the classroom. After that experience we realized what difficulties where found while designing a CMPG. So we decided to build guidelines for the design of a CMPG. We tested these guidelines designing and implementing a new version of the game: Osos 2. This game was tested in forty students while we analyzed how these guidelines behave. The 3D modeling needed to visualize the Game was built by Juan Jose Andreu.

1.2. The Game: Osos 2

1.2.1. Overview

Osos is a game to teach ecology balance for students. This game is designed to be played by ten students using a mouse and sharing a common screen between them. It is meant to last for about forty minutes of continuous play. The idea is that the teacher uses this tool for a better comprehension and enjoyment of the class by the students while they study the Food Chain Chapter.

1.2.2. Story

1.2.2.1. The Plot

The game is based on a planet which needs to be rescued. The planet AEquilibrium wants to avoid the extinction of their species. AEquilibrium has three species: Flora (producer), Wumpus (hervibore) and Gengas (carnivore). This three species have lived in ecological balance for a long time. They coexist as species related in a food chain. Figure 1.11 Chain shows the relation between the species.

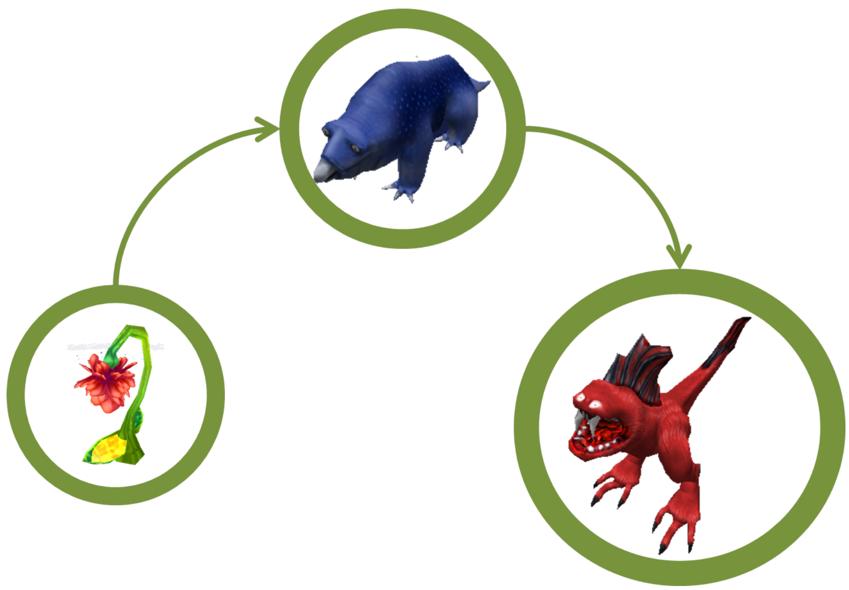

FIGURE 1.3. Food Chain.

But something has happened in AEquilibrium and they called you for their aid. It is not known the origin of the problem and you need to solve it. The players will choose their own character and class to explore this world. The classes availables are Shaman or Hunter. Choosing their class is very important because they will have different abilities. The difference with this abilities will be crucial in the way they play. To solve the game it is necessary to have both of the classes playing collaboratively. While the hunter has more vitality and strength the shaman can use magic to heal his partners and plant seeds. Figure 1.4 the screen capture while players select their characters.

FIGURE 1.4. Character Selection.

But keeping the ecosystem alive is not the only problem given to the students. Their characters also have needs. They have to feed them periodically, if not their characters will starve and lose life. They could die if this happens for a long time. To get food the characters have to hunt the animals and pick the meat they drop. They must do this carefully, if they kill all the animals from one specie it will disappear forever. Players must find the way to keep themselves alive while they protect the species from disappearing of the planet AEquilibrium. Along the game players will learn new abilities to use in the pursuit of ecological balance.

1.2.2.2. Game Elements

(i) Game Characters

The game character is the way the student interacts in the world. It can move freely around it (they have to go all together) using the mouse. The student has to take care of him and help the others in order to success in the game. Every game character has a name and its own hair style and color. Also the hair color is the same that the mouse pointer. The mouse pointer it is used to move and make actions like attacking, eating or grabbing objects. The action that the character is going to execute is defined by the mouse pointer. The mouse pointer changes its aspect giving feedback about the action that is going to execute. Figure 1.5 shows a character with his mouse pointers.

FIGURE 1.5. Character and his pointers.

(ii) Game Classes

Every player in the game has to choose a character and his class. The class refers to the abilities the character is going to have in the game. These abilities are going to help him and his friends to finish the game. There are two classes available: Shaman and Hunter.

- Shaman: the shaman is a magical character. It uses mana to plant seeds and heal his partners. Even though the shaman can attack beasts, it is no recommended to do it because his vitality and strength are not so reliable. Figure 1.6 shows a Shaman.

FIGURE 1.6. Shaman.

- Hunter: the hunter loves fighting with animals. It prefers to pursue the most horrible beasts rather than the easy to catch. While hunting these beasts it could get some food from them. He has to protect their friends using his vitality and strength. Figure 1.7 shows a Hunter.

FIGURE 1.7. Hunter.

(iii) Flora (Producer)

Flora is the producer in the food chain. Flora grows from the seeds that other Flora germinates. Time to time a flora germinates a seed. This seeds can be planted by Shaman using their magic. Flora is the food of the hervibore's. Figure 1.8 shows flora.

FIGURE 1.8. Flora.

(iv) Flora's Seed

Flora appears with the combination of Shaman's magic and seed. These seeds are germinated by flora time to time. They are yellow and jump off the flora when it is ready to be planted. Figure 1.9 shows a seed.

FIGURE 1.9. Seed.

(v) Wumpus (Hervibore)

Wumpus is the hervibore in the food chain. Wumpus reproduce time to time. They also eat Flora and are eaten by the carnivores. When a wumpus dies they throw a piece of meat that can be eaten by characters to gain life. Wumpus are peaceful animals but they are hard to kill. Figure 1.10 shows a Wumpus.

FIGURE 1.10. Wumpus.

(vi) Wumpus Meat (Food)

Wumpus meat is thrown by wumpus when they die. This food can be used by characters to eat and stop starving. Time to time characters starve so they need to eat, wumpus meat is their food. Wumpus need to be hunted to throw the meat. Figure 1.11 shows Wumpus Meat.

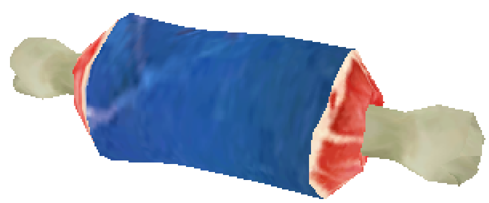

FIGURE 1.11. Food.

(vii) Gengas (Carnivore)

Gengas are in the top of the food chain, they are carnivore's. Gengas are dangerous and fearless creatures. They will attack players as soon as they get near to them. They are very difficult to kill and it is going to be needed a group of characters to take one off this down. Gengas reproduce time to time. They will eat Wumpus periodically so you need to protect Wumpus from Gengas when they are in danger, but if there is no Wumpus around they could die of hunger. If a character gets hurt by a Genga the healing magic of the shaman can cure him. Figure 1.12 shows a Genga.

FIGURE 1.12. Genga.

1.2.3. Game Presentation

In this section we will present how the game is presented to the user. We will divide our game in four main phases:

- Normal Game.
- Storytelling.
- System Instructions.
- Teacher Instrucions.

1.2.3.1. Normal Game

For this phase we divided the screen in two spaces. The first space is named Avatars Area and its located in the top and the bottom of the screen. Each player has his own Avatar. An Avatar provides the player all the information that is necessary to play the game. The second space is called the playing Area and is where the players move freely exploring the world.

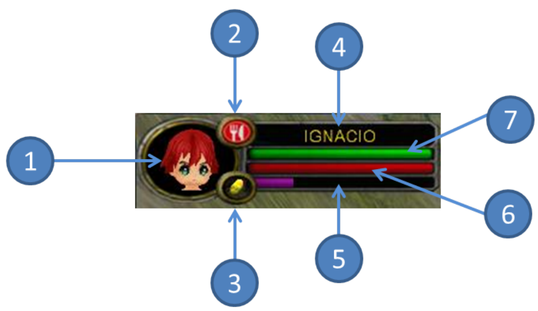

FIGURE 1.13. Player Avatar.

The information provided by the avatar is provided by Figure 1.13:

(i) A picture of the player units (the avatar).
(ii) Whether the player is hungry or not.
(iii) Whether the player is grabbing an item or not.
(iv) The players name.
(v) A experience bar (level).
(vi) A mana bar (magic).
(vii) A energy bar (life).

A complete picture of how these areas are arranged is showed in Figure 1.14.

FIGURE 1.14. Normal Game.

1.2.3.2. Storytelling

This moment of the game is normally a transition where the story is told. The avatars are hide and the story text starts to roll. This is accompanied with camera movements. Figure 1.15 is an example of this.

FIGURE 1.15. Storytelling.

1.2.3.3. System Instructions

Games usually include Hints or System instructions. We don't want to waste time on kids understanding these instructions because our goal is the curricular content. That's why we avoid to overload them with information. To achieve these we just show them the instructions on how to play and hide al the rest. Figure 1.16 shows the instructions needed to plant.

FIGURE 1.16. Planting Instructions.

1.2.3.4. Teacher Instructions

As this game is played within the classroom, the teacher needs a role in the game. That is why we provide him with the capability to pause the game and move the camera freely. In that way he could explain curricular contents or game issues. Also he can give time to the students to solve problem related to the game. Figure 1.17 shows a timer given to the students so they could finish the task in time.

FIGURE 1.17. Teacher Instructions.

1.3. The Software

1.3.1. Working with the Framework

1.3.1.1. Overview of NeoAxis Engine

NeoAxis Game Engine is an all-purpose, modern 3D graphics engine for 3D simulations, visualizations and games.

NeoAxis Engine is a complete integrated development environment for creating interactive 3D graphics including 3D virtual worlds, AAA games, and realistic simulations. The system comprised of both a real-time 3D engine and a suite of full featured tools described in Table 1.1. NeoAxis Engine tools forms a complete content pipeline. You can edit every aspect of the world, including game-object attributes, set triggers and level logic.

For the implementation of the game we used all this tools. The GUI Editor, Input Device System and Game Object System do not provide all the capabilities we need to correctly implement this game. To solve this we expand the tools for our requirements. This is explained in detail further in the document.

1.3.2. Developing with NeoAxis Engine

NeoAxis Engine is built in C# over .NET 4.0 platform. It is designed to use all there capabilities with Visual Studio 2010. To create a new Game we need to implement all the Game Logic, Multiple Mouse Handling and GUI integrated with Multiple Mouse. The tools that need extension are:

- Game Object System
- Input Device System
- Gui Editor

1.3.2.1. Game Object System

Game Object System is a software environment used for creating project's game logic. By means of Game Object System world's game logic is created. Game Object System determines what elements the world consists of and how it runs (in other words, all aspects of project's game logic). The Game Object System is a way to determine all game logic objects as well as the way they interact. Anything in the game world is a game object whether it is an animal, a bonfire or a landscape.

- Game Object Class

TABLE 1.1. Neoaxis Tools.

Tool	Description
Expandable Map Editor	Integrated WYSIWYG world editor is a powerful object placement toolkit for the easy building of game scenes.
Resource editor	Allows developers to fully configure all types of game objects, and to adjust objects visually. It is includes creation of appearance, configuring physics, particle systems, and all other attributes of game objects visually.
Expandable material editor	An intuitive visual tool for designing materials and shaders.
GUI editor	GUI Editor is intended for the creation of end-user controls, menus, dialogues, windows, HUD screens and in-game 3D GUI.
Physical model editor	Tool for the creation of physical models for game objects.
Particle system editor	Powerful tool for the creation of various particle systems.
Terrain editor	Terrain Editor, a landscape design tool. Supports geometry editing and painting of alpha layers onto terrain to control blending, collision data, and support of detail and normal maps.
Static lighting calculation tool	Build in static lighting calculation tool with lightmaps and irradiance volume support.
3D modelling packages exporters	NeoAxis Engine includes many model exporters for 3d modelers such as: 3D Studio Max, Maya, SoftImage XSI, Blender, Milkshape.
Expandable Input Device System	Expandable tool for implementing your own custom input device controllers.

The basic characteristic of any game object is its game class. The class determines object's attributes and logic, i.e. object's behavior. Game object classes are created by programmers. Osos Object Classes are shown in Table 1.2.

Same class can be the basis for different game objects. For example, game characters (such as Shaman or Hunter) belong to the **CMPRPGGameCharacter** class. These characters share same logic but have different parameter values (life, mana, damage). This parameters are set in the **game object type**.

- Game Object Type

  Any object has its **game type**. A game object type is always based on a particular game object class, specifying object's parameter provided by the given class. For example, a Game Character parameter is MpMax. MpMax means the maximum mana the character may have. This value will be greater for the Shaman and lower for the Hunter, but will work with the same logic. Increasing periodically until they reach MpMax and lowering its value while they use magic. Game object types are stored in **.type** files. You can create and edit game object types in the Resource Editor. Parameters are also inherited. Osos Object types are shown in Table 1.3.

TABLE 1.2. Osos Object Classes.

Game Object Class	Description
CMPRPGUnit	Every unit class of the game is an extension of this class. It is in charge of controlling the life cycle of a unit in the game (birth, development and death).
CMPRPGPlant	This class is in charge of the logic of a plant (Flora) in the game. Time to time this class creates a seed. This seed could be taken by a Shaman to be planted.
CMPRPGLiving	This class is in charge of the logic for the living classes of the game. Moving, being hungry and starving and are the functionalities.
CMPRPGAnimal	This class is in charge of the logic for the animal classes of the game. The essential functionality is to manage the breeding and eating.
CMPRPGCarnivore	This class is in charge of the logic of carnivore classes of the game. Carnivores attack when characters approach to them.
CMPRPGHervibore	This class is in charge of the logic of hervibore classes of the game. Hervibores eat plants and escape when characters approach to them.
CMPRPGCharacter	This class is in charge of the logic of character classes of the game. Eating, pick/drop item and using magic are the functionalities.
CMPRPGShaman **CMPRPGHunter**	Abstraction layer for further implementation. No extra functionalities added
CMPRPGInventory	This class is in charge of the inventory handling done by the characters.
CMPRPGFoodItem	This class is in charge of the logic of food items. Represents an object that could be eated.
CMPRPGSeed	This class is in charge of the logic to plant seeds. Represents an object that could be planted.

TABLE 1.3. Osos Object Types.

Game Object Type	Parameters
CMPRPGUnitType	Mass, height, radius and physics position.
CMPRPGPlantType	Fruit count, fruit type, time to grow and time to harvest.
CMPRPGLivingType	Damage, attack delay and time to hunger.
CMPRPGAnimalType	Food list, time to reproduce, time to move, time to starve and time to grow.
CMPRPGCarnivoreType	No extra parameters. Abstraction layer for further implementation.
CMPRPGHerviboreType	No extra parameters. Abstraction layer for further implementation.
CMPRPGCharacterType	Maximum life, maximum mana, hunger damage, starve damage, time to hunger, time to starve, time to regenerate mana and attack delay.
CMPRPGShamanType **CMPRPGHunterType**	No extra parameters. Abstraction layer for further implementation.
CMPRPGInventoryType	Maximum items.
CMPRPGFoodItemType	Food duration and regeneration.
CMPRPGSeedType	Breed time.

- Class Hierarchy

  Game object classes can be derived from other classes forming a class tree. For example, the **CMPRPGUnit** class enables the creation of object's for the game and all the initializations that are needed (meshes, physics, size, position). **CMPRPGLiving** class sets the logic specific for living classes (such as hervibore, carnivore, and character). Game objects of this class can born, live, move and die. **CMPRPGAnimal** sets the logic for the animal classes such as CMPRPGCarnivore and **CMPRPGHervibore**. This logic considers hunger, starve and breed.

CMPRPGCarnivore may attack possible predators (such as Characters), while **CMPRPGHervibore** escape from possible attackers.

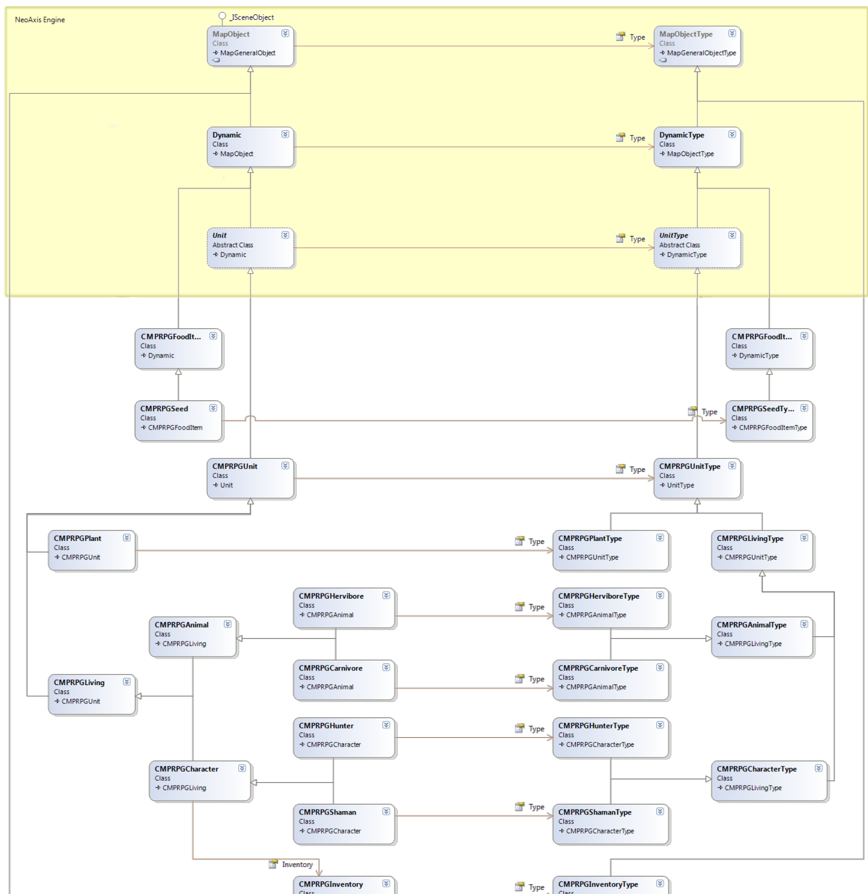

FIGURE 1.18. Class Hierarchy.

The Game Object Classes and Game Object Types are shown in Figure 1.18 with the hierarchy included.

1.3.2.2. Input Device System

Input System is designed to retrieve data from user and process it. The user controls the application by means of input devices trough the input system (i.e. it is a link between the device and the application). Currently the NeoAxis Engine input system supports the following devices:

- Mouse
- Keyboard
- Joystick, Gamepads and Racing Wheels
- Xbox360 Controllers

The problem is that we need to handle at least ten mice as input. That is why we use the Custom Input Device System.

(i) InputDeviceManager Class

The InputDeviceManager Class is in charge of handling all the input devices (provides a List with all of them) that are used in the game. This class is Singleton which provides a unique instance and global access to it. This class has two main methods described in Table 1.4.

TABLE 1.4. Input Device Manager Methods.

Method	Description
RegisterDevice (InputDevice device)	Device must call this after creation to register itself in the system. Parameters: [device] The device that is going to be registered.
SendEvent (InputEvent event)	The system is notified that a state has changed by this method. [event] The event that describes the state that changes.

(ii) Input Device Class

This class represents the input device. It has three main methods that describes the device life cycle: creation, state updates and shutdown. This methods are described in Table 1.5.

TABLE 1.5. Input Device Methods.

Method	Description
InputDevice(string name)	Constructor of the class, manages the creation of the device. Parameters: [name] The name of the device.
OnUpdateState()	It is called every time a state changes. It must read the data to update the state of the device. Then should call InputDeviceManager.Instance.SendEvent to communicate the system that the device has changes its state.
OnShutDown()	Shutdown the device and removes it from the InputDeviceManager list.

(iii) Input Device Event

Describes general input event. Custom events should be generalized from this class. For example, a multiple mouse device event should extend this class and incorporate all the data necessary to handle the event. It is the parameter sent via **InputDeviceManager.Instance.SendEvent** method.

1.3.2.3. Raw Input Sharp API

As said before we need to incorporate the handling of multiple mouse. Using the Custom Input Device System we communicate the devices with the engine. But first is necessary to get this information from raw data provided by the OS. To get the raw data we use the RawInputAPI.

(i) Raw Input Sharp API: Registering Devices

RawInputSharp API registers the devices from the User32.dll[1]. This is done by System Call provided by the OS. Mouse Devices are registered to the window where the engine is running. This API implements a class named RawMouse. It

[1]Windows SDK

is in charge of keeping all the information necessary to manage a mouse device input including events and movements. This is our entrance point for the hardware information needed to manage the mouse (Figure 1.20).

(ii) Raw Input Sharp API: Updating Devices

RawInput API needs to update the data every time it changes. Windows uses messages to inform every application that has devices subscribed to it. This messages are received by the WindowsWndProc function. WindowsWndProc is an application-defined function that processes messages sent to a window. Every time WindowsWndProc is called we update the values of our device class (Figure 1.19).

```
protected const int WM_INPUT = 0x00FF;
/// <summary>
/// In charge of processing RawInput data. Every mouse data is overwritten.
/// </summary>
/// <param name="message">The message.</param>
/// <param name="wParam">Additional message information.</param>
/// <param name="lParam">Additional message information.</param>
void OnWindowsWndProc(uint message, IntPtr wParam, IntPtr lParam)
{
    switch (message)
    {
        case WM_INPUT:
            MMouseManager.Instance.Update(lParam); //relative mode...
            break;
    }
}
```

FIGURE 1.19. OnWindowsWndProc.

1.3.2.4. Customizing Input Device System

There are three things we need to handle in order to customize (or extend) the Input Device System provided by the NeoAxis Engine.

(i) Create an extension of InputDevice Class.
(ii) Create a manager for our devices.
(iii) Create multiple mouse events.
(iv) Integrate RawInputSharp API to NeoAxis Engine.

(Figure 1.20) shows the whole picture of how the customization was made.

(i) MMouseDevice

This class extends the InputDevice class provided by NeoAxis Engine. It contains a RawMouse object in order to obtain the information from the raw data. Every time the raw data is updated MMouseDevice is updated and the events are triggered. Table 1.6 shows MMouseDevice class method's.

TABLE 1.6. MMouse Device Methods.

Method	Description
MMouseDevice (RawMouse raw, Texture text)	Constructor of the class, manages the creation of the device. Parameters: [text] The texture that is going to be rendered. [raw] RawMouse object that has the raw mouse data.
OnUpdateState()	It is called every time a state changes. Reads the data from RawMouse such as, mouse position, pressed buttons and wheel scroll variations. Every time a state is changed the event is sent via InputDeviceSystem.Instance.SendEvent method.
OnShutDown()	Shutdown the device and removes it from the MMouseDeviceManager list.

(ii) MMouseManager Class

This class is in charge of handling multiple mouse devices. The responsibilities of this class are:

(a) Initialize the devices.
(b) Register the devices to WindowsWndProc function.
(c) Update the devices.
(d) Draw Mouses.

The MMouseManager Class is implemented as a Singleton Class due to necessity to have global access to it and a unique instance.

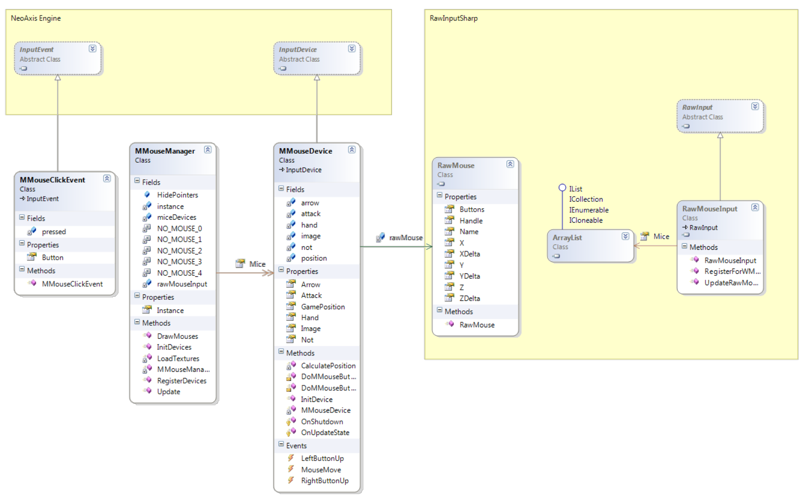

FIGURE 1.20. IO Class Diagram.

(iii) MMouseClickEvent

Describes a multiple mouse click event. This class extends the Input Event class provided by NeoAxis. Contains the information about the button that was pressed. We did not implement wheel scroll or movements thru the Input Device System due it was not necessary to communicate the engine about thee states.

1.3.2.5. Gui Editor

The Graphic User Interface Editor Figure 1.21 provided by NeoAxis is a framework for creating controls, menus, dialogs, windows and screens. This system can be enhanced by adding new classes and controls.

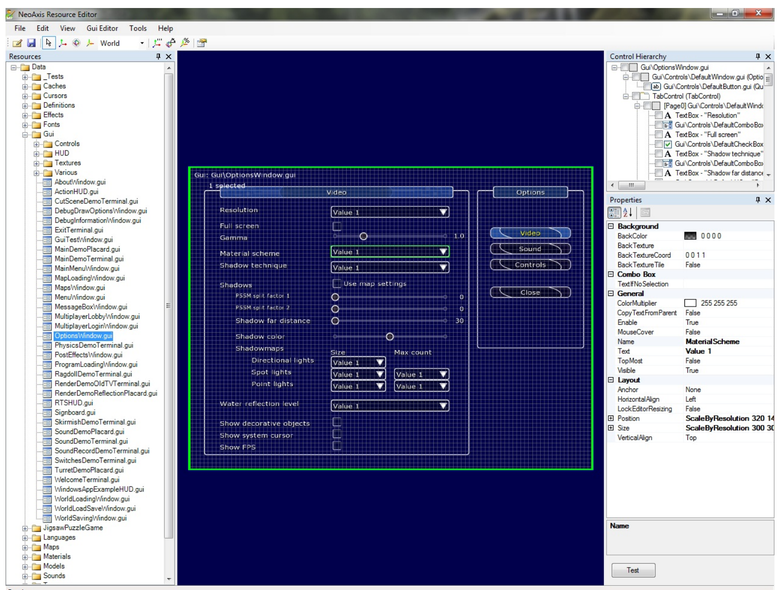

FIGURE 1.21. Gui Editor.

NeoAxis provide a basic set of classes for the user interface:

- Button
- CheckBox
- ComboBox
- EditBox
- ListBox
- ScrollBar
- TabControl
- TextBox
- VideoBox

This classes are ready to be used with the mouse or keyboard. Triggering events and their respective handlers are already usable. The problem is that we need that our GUI elements are aware from the events of multiple mouse.

(i) EControl Class

The EControl Class given by NeoAxis represents the base class for every GUI element. The features provided by this class for handling events are listed in Table 1.7.

TABLE 1.7. EControl Event Handling.

Name	Description
Keyboard Handling	Handles key down, key pressed and key up events.
Mouse Handling	Handles double click, mouse down, mouse move, mouse up and mouse wheel events.
Custom Device Handling	Handles the events that are sent by the Input Device System.

We need to extend the handlers to be capable of using multiple mouse events.

1.3.2.6. Customizing GUI Elements

Using the Custom Device Handling capability provided by the EControl class we are able to extend it for multiple mouse events. EControl class is subscribed to the custom device events thrown by the Input Device System. Moreover the method *OnCustomInput-Device(InputEvent event)* is the handler for this events. We just need to identify the event of the type MMouseClickEvent, and verify if the mouse is over the region of the Gui element. After this verification we call our own Left/RigthMMButtonUp event. With this implementation it will be transparent for any user who wants to create their own multiple mouse Gui elements, such as shown in Figure 1.22.

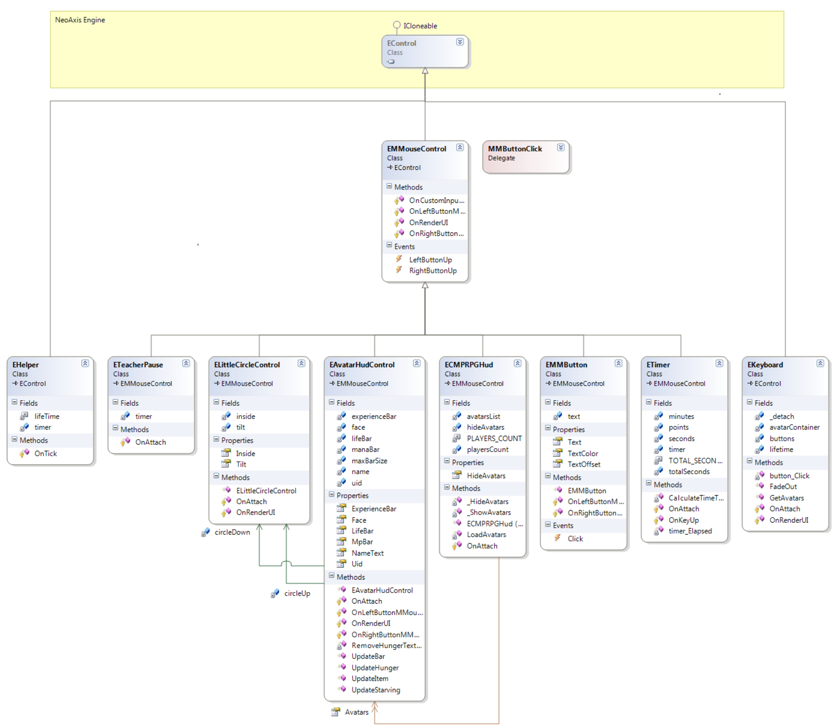

FIGURE 1.22. Gui Class Diagram.

1.3.2.7. Connecting Software Elements

Now that our software elements are described we can understand the way they interact, Figure 1.23 shows a Sequence Diagram of this interaction. The phases the system passes when an event is triggered are:

(i) Player triggers a Mouse Event *(e.g. by clicking the left button of his mouse)*.

(ii) The OS captures this information by reading Raw Data. We access Raw Data with the Raw Input Sharp API.

(iii) MMouseManager reads the states of the Raw Mouse and updates the MMouseDevice state.

(iv) MMouseDevice triggers an event on Game Engine using the Input Device System.

(v) All the Engine is notified by this event and changes are made.

(vi) Player see's the effect on screen *(e.g. picking up an item)*.

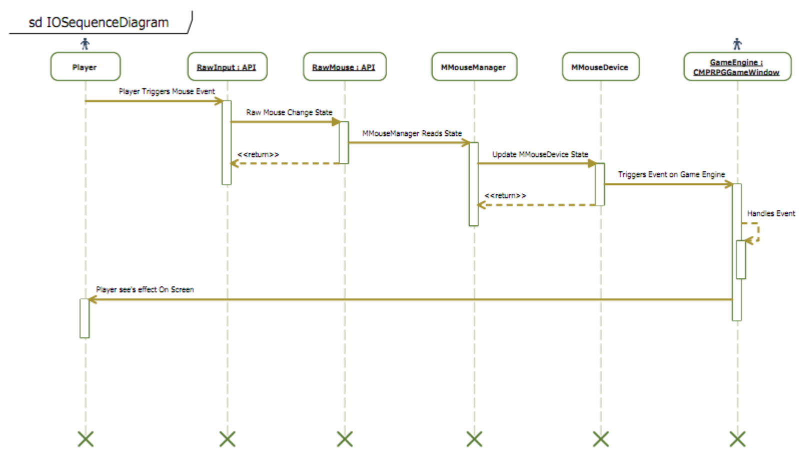

FIGURE 1.23. IO Sequence Diagram.

1.4. Conclusions

This game is the re design of a previous game (Susaeta, H, Jimenez, F., Nussbaum, M, Gajardo, I, Andreu, J, & Villalta, M, 2010), which was the thesis of Felipe Jimenez where I worked as a developer. The previous game was designed and implemented pursuing the same goals: teaching the students the food chain using a game. That game was tested with the students several times. Those testing taught us how a game behaves in the classroom, with their strengths and weaknesses. Also it showed us what we did not considered in the design and should have. This is the reason why we consider re-designing it. We want to completely understand how a CMPG needs to be designed to achieve the goals it is meant to: teach curricular content using a game, be engaging and have a clear narrative.

The conclusions left out by the two CMPG experiences could be resumed in the next points:

- Integration.
- Trade off Issues.
- Students Behavior.

1.4.1. Integration

A CMPG should never forget the elements inside a traditional classroom (teacher, students, physical area and the behavior expected). Things to be considered are:

(i) It cannot replace the role of a teacher. It should give him a new tool for teaching in a more complete way. Using the ludic and immersive characteristics of a game such as: fantasy, storytelling and graphics.
(ii) It must respect the times and spaces that are taken in a normal class.
(iii) The class does not have to be turned into a '*Learn how to play the game*'. The learning of the playability should not take too much time. The discussion generated by the game is the goal of the activity.

1.4.2. Trade off Issues

While designing a game we will always face trade off issues. This trade off need to be handled in a way it strengthened the classroom experience. Dealing with students is always unpredictable. The rule is: *let them play and learn*. These trade off issues are:

(i) The CMPG will show the users information that may need to be processed and discussed. It is the role of the teacher to know when the game should be paused and a discussion must be started, and when to let the students play.

(ii) A CMPG will motivate students, but it is needed to handle their motivation. Sometimes student exaltation interposes with their learning. Kids love fantasy with great stories and colors, this is a big strength you need to handle.

(iii) Students love playing games, rules of the activity must be defined previous to the start of the game so no over expectations need to be controlled.

(iv) Complex graphics gives a better experience of the game, but also adds complexity. Try to keep things as simple as possible without being boring.

(v) Same as graphics, sounds gives a better experience of the game, but also adds complexity. In Osos 2 we use low volume music game in order to keep concentration in the activity.

1.4.3. Students Behavior

Kids do not know how to work on teams or to organize themselves to define strategies. If the game needs strategies and teamwork to be accomplished they must be induced by the teacher. Some hints may be helpful. Leadership and teamwork will arise if the game is well designed. Reflections about these must be taken into consideration by the students to learn about these. In the game we developed we did not consider these reflections. Intuition said that roles for teamwork experience could be introduced. There is a chance to teach students how to behave while playing in a team in which they take different roles.

1.5. Future Work

This investigation concluded that well designed CMPGs work fine. Our experiments and results serve for short term conclusion. Long term experiments are needed to validate this tool as an educational instrument. Also it is needed to explore more deeply how game characteristics such as: esthetics, narrative, cinematics, sounds, user interface and playability affect the performance of the game in the classroom. Our conclusion considered all of them in a general way. Particular studies for each of these are needed to obtain stronger conclusions about CMPGs.

2. DESIGN GUIDELINES FOR CLASSROOM MULTIPLAYER PRESENTIAL GAMES

2.1. Introduction

Videogames present many possibilities for developing knowledge and improve teaching and learning practices in schools, especially those of a collaborative and cooperative nature (El-Nasr et al., 2010). Within their broad potential, what stands out the most is: increasing students' interest in learning, adapting to the user's tempo, improving and strengthening the acquisition of information and awakening and maintaining motivation (Mayo, 2009).

As Amory (2007) points out, designing videogames for education implies integrating instruction strategies and ludic activities, in benefit of certain educational goals. The absence of this integration is one of the factors that inhibit the use of videogames in the classroom (Baek,2008). Instruction strategies refer to the development of methods that make the curriculum operative within the context of the game, favoring learning (Serin, Serin, & Saygili,2009). On the other hand, ludic dynamics refer to the mechanics of the game and a relation to theplayers that assures motivation and playability (Fabricatore, Nussbaum, & Rosas, 2002). There is also a correlation between videogames design patterns and the development of cooperative relationships among players (El-Nasr et al., 2010).

When linked to new teaching practices, videogames improve educational achievements in students that are usually excluded by traditional teaching methods (Virvou, Katsionis, & Manos, 2005). In particular,MassiveMultiplayer Online Games - (MMOGs) develop a type of technology that increases interactivity and participation in the virtualworlds offered to the user. This is explained by these games' specific characteristics: the design of a fantastic atmosphere that favors the participant's immersion, interactivity among participants through the virtual world, and a story and script structured around challenges that develop critical thinking, teamwork and strategies for problem solving (Dickey, 2007).

In MMOGs each player actively participates in the game fromtheir own individual computer, connecting online with other players, with an administrator who is in charge of organizing the rules and making sure the game is playable. Since the rules, objectives, accessories and tools of the game are built by the designers (Zagal, Nussbaum, & Rosas, 2000), this active participation could encourage learning the rules of a specific area of scienti?c knowledge (Gee, 2005). The use of games has an important educational potential, both in and out of the classroom.

Within the classroom, videogames could be the answer to the education community's concerns. For teachers, they could become a valuable tool that incorporates collaborative work and technology (Alvarez, 2006). Videogames can be used to cover certain points in the curriculum, but they must be designed so as to maintain the fundamental characteristics of the act of playing: freedom to explore, freedom to make mistakes, freedom to experiment, and the possibility of building an identity (Osterweil & Klopfer, in press).

Efforts to bring videogame computer technology to the concrete experiences of the classroom have not been particularly successful. Many educational videogames are not engaging. They don't incorporate fun into learning, resulting in repetitive, poorly designed tasks that don't help students' progressive comprehension (Kirriemuir & McFarlane, 2004) and are centered on simple 'drill and practice' models (Squire, 2003). Others get stuck on 'edutainment', meaning focusing on the ludic aspect, and don't challenge students to develop hypotheses or problem solving strategies (Sancho, Fuentes-Fernandez, Gómez-Martín, & Fernandez-Manjón, 2009). The implementation of design guides that incorporate the requirements of both education and videogame design is still a pending task (Moreno-Ger, Burgos, Martinez-Ortiz, Sierra, & Fernandez-Manjon, 2008; Squire, 2003).

In order to take advantage of the great interactive, motivational and participatory potential of MMOGs, we have studied how to incorporate them into the classroom (Nussbaum et al., 2009; Susaeta et al., 2010). In our setup, the game is carried out on a screen which is projected at the front of the classroom, through which the students interact with the virtual world and amongst themselves in the shared space (Figure 2.1). Each player has his own input device, which allows him or her to control his or her character within the game. Because the players are inside the classroom, we replaced the word 'Massive' for 'Classroom', and because they are all present in the same physical space, interacting in person, we substituted

’Online’ for ’Presential’, thus obtaining Classroom Multiplayer Presential Game (CMPG), where there is a link between the mechanics of the game and the teaching process. Just as there is a game master in MMOGs, in CMPGs the teacher plays the role of game mediator, with the educational contents laid out in the virtual world, as well as in the direct interaction amongst students.

FIGURE 2.1. Position of the screen and participants inside the classroom. .

This article's objective is to develop and systematize guidelines for the design of CMPGs that support teaching activities linked to curriculum contents in the classroom. To devise these guidelines we developed a three-step process. First, we evaluated a previous implementation of a CMPG to teach the concept of the food chain to 6th grade students, to detect its problems and weaknesses. Second, based on the problems detected, we used existing literature in educational game development, educational multimedia activities and commercial game design to de?ne a series of guidelines aimed to solve these problems. In the third and ?nal step,we applied these guidelines to redesign the CMPG and tested the new version of the gam ewith a group of students, analyzing how useful the guidelines were in designing the new version of the game.

2.2. Building a CMPG to teach the food chain to 6th grade students

2.2.1. Description of the game

The use of computer technology in the classroom has proven to be effective in achieving motivation (Ke, 2008b), collaboration (Cortez, Nussbaum,Woywood, & Aravena, 2009) and learning results (Carbonaro et al., 2008; Plass et al., 2010a; Zurita, Nussbaum, & Shaples, 2003). Two kinds of educational objectives can be reached: transverse, pertaining to the development of an ethic conscience, personal self-afirmation and coexistence with others; and vertical, pertaining to the progressive grasp on the contents of the school curriculum (Ministerio de Educación, 2002).

The CMPG to teach the concept of the food chain (Susaeta et al., 2010) was included in the ecology curriculum unit. The game uses interactivity and immersion to boost the achievement of transverse and vertical goals in the school curriculum at 6th grade level (Ministerio de Educación, 2004). The specific objectives and expected learning outcomes of the game are shown in Table 1. The game was designed for ten concurrent players because this was experimentally shown to be the maximum number of avatars that can simultaneously play on one conventional screen (1.5 m x 1.5 m) (Susaeta et al., 2010).

The ecology game includes a number of different quests following the CMPG model (Echeverría et al., 2011), each one designed to emphasize a key teaching objective. They are arranged linearly so that the end of one marks the beginning of the next. This order is determined by the curriculum structure set by the Chilean Ministry of Education and ensures that the course concepts are delivered incrementally.

Students participated in the virtual world after choosing a character with specific abilities: 'Shaman', with the ability to cure diseases and plant seeds, or 'Hunter', with the ability to hunt. Students controlled their character by using the left and right buttons (one mouse per student).

Three of the game's quests are aimed at achieving specific vertical objectives **(Table 1)**. In the first quest, a new foreign species joins the ecosystem. This new predator starts feeding on the predators that were previously at the top of the food chain, transforming the ecosystem. The players must protect the ecosystem by scaring away the new species; to do this they must approach the new predator species in groups of no less than three players so as to lead it away from the playing zone.

In the second quest, a strange parasite starts to affect all the animals and it turns into an epidemic. The players have to contain this epidemic. To do this, two roles are defined in the game: the hunter, who paralyzes the infected animal, and the Shaman, who later cures it.

In the third quest, there is an explosive reproduction of the herbivorous population, becoming a risk to plant life. In the virtual setting, the plant ecosystem comprises three areas and its existence is at risk from this increase in herbivorous predators. The players must work together to prevent these herbivores from destroying the ecosystem by killing off plants in each one of these three zones. The players must plant more plants, kill the herbivores when they become too numerous and ensure that there are always carnivorous predators in each zone.

The game is used as a supporting tool by the teacher to conduct the class, who is in charge of the computer which was running the game. As the students advance in the game, the teacher can pause the game-play and use the whiteboard to explain a specific concept about the ecological balance that was observed in the game. The teacher also fulfills the role of mediator in the discussions between the students, relating the strategy to solve each quest and by guiding the students, when necessary, according to the teaching objectives.

2.2.2. Exploratory Study

An exploratory study was conducted to understand how the players interacted with the game (Susaeta et al., 2010). The study involved ten 7th grade students, ages ranging from 12 to 14, in a in a regular middle socioeconomic status primary school of Santiago de Chile. In the study, one of the researchers acted as the teacher, guiding the students game sessions and mediating their interaction. The game was played in a traditional classroom, but the chairs were relocated to have the students closer to the screen and facing each other (Figure 2.1). The results of this study showed that the CMPG favored the achievement of vertical goals in students, improving the learning results of content relating to the food chain through the application of the corresponding contents to the virtual world offered by the game. With regard to transverse goals, promotion of responsibility, autonomy, reflection, and teamwork could be observed in students.

The methodology used to analyze the player's experience with the game included both ethnographic observations during the game session and discussion with the students after the game was played. The qualitative observations were gathered by two researchers through the different quests of the game, and they were classified into two types: individual work and collaborative work observations. The individual work observations were focused on two dimensions: identification of elements in the game and activity understanding. The collaborative work observations were focused on four dimensions: exchange of information between players, negotiation, leadership and coordination.

The results of the observations made during the game session and the discussion with the students showed that the experience was not without difficulties, and that many aspects of the game could be improved. A careful review of this initial experimental study allowed us to identify a series of specific problems and weaknesses in the game:

(i) *Lack of feedback and guidance*: There is feedback at the end of the quest, but not during the process. Because of this, players cannot tell which actions, whether individual or collective, are best for solving the activity. Players tend to forget, or mistake, their character's abilities, lessening on-screen participation.

(ii) *Unclear relation between game actions and learning content*: Players lose the quests because they don't understand the interdependence between the elements of the food chain.

(iii) *Unclear and weak narrative*: The game's activities are not sustained, or don't develop the motivational potential of the narrative.

(iv) *Too many concepts presented simultaneously*: Quests cover several food chain concepts simultaneously. This adds fantasy to the game, but makes the didactic presentation of the food chain difficult. Quest resolution demands collaborative actions with different levels of difficulty to be carried out.

(v) *The teacher role in the game was not clearly defined*: The absence of predefined criteria and guiding questions to support the teacher's role diminishes student participation.

(vi) *Lack of face to face interaction*: Players understand the quests and the fact that the solution requires direct dialogue between them. However, the game does not offer enough favorable conditions for a collaborative dialogue.

(vii) *Lack of collaborative game mechanics*: The learning of transverse goals was affected by the absence of collaborative mechanisms to be discovered in the game. Players with better videogame abilities may lose interest in a virtual world where they have nothing new to discover.

(viii) *Poor use of screen space*: At the beginning of the game, the characters and events are located on certain parts of the screen. This generates grouping and space misuse, creating confusion.

(ix) *Unrecognizable elements*: Participants mistake their characters during the game. The interaction between characters and the screen elements is not evident.

(x) *Inaccessible language*: During the activity, students don't read the instructions on the screen. Texts are too long, and there are parallel activities on screen.

(xi) *Information overload*: The individual information surrounding each character confuses players when they interact.

(xii) *Lack of coordination between all the aspects of the game*: The ludic, instructional and collaborative dimensions of the game were not explicitly coordinated. This affected the integral comprehension of the game as a whole.

2.3. Guidelines for the design of a CMPG

For each of the problems described in section 2.2.2, we propose a design guideline that helps to solve the specific difficulties associated with the problem. The guidelines we present in this section for the development of CMPGs consider two contributing factors: instruction strategies and game elements (Amory, 2007). The design guidelines are grouped in six categories: game mechanics, game progression, methodology, collaboration, on-screen information and holism.

2.3.1. Game mechanics

Game mechanics for learning describe patterns of behavior through which learners players interact with and learn from the game, and are designed in pursuit of optimal insertion into a classroom context. In this sense, game mechanics guidelines answer the question: how should the game be played?

2.3.1.1. Interactivity and guidance

Considering that unguided discovery does not work, Domagk, Schwartz, and Plass (2010) propose a model for interactive multimedia learning, i.e. learning activities where the students interact using multiple media (visual, audio, etc.), an example of which are educational games. This model observes that interactivity refers to reciprocal activities among the action possibilities offered by the multimedia system, where action, motivation, and the student's cognitive processes are oriented towards achieving learning. Consequently, designing an educational game requires interactivity guides to orient the student's actions, which implies concepts such as feedback, notices and action suggestions that are specific to each student (Domagk, Schwartz, & Plass, 2010).

Feedback is inherent in videogames; it maintains participation, and informs players of their achievement level (Aldinger, Kopf, Scheele & Effelsberg, 2005; Ang et al., 2008; Moreno-Ger et al., 2008). If the game feedback is delivered in a constant manner throughout the game it can also work as reinforcement to participants' partial achievements (Osterweil & Klopfer, 2009).

In collaborative games it is important to differentiate between two types of feedback: individual feedback, which is targeted to each individual player, and collective feedback, which is targeted to all the players, or a subgroup of players. Individual feedback promotes the experience of a role within the game (Lim, 2008), while collective feedback orients interaction between participants (Lim, 2008; Sancho et al., 2009). Feedback to individual and collective action is efficient when it is coherent with the game's design for the flow of activities (Dillenbourg, 2002). In other words, an appropriate design, which promotes learning, is achieved with precise, timely, and constant information regarding success and failure in the participants' performance (Rosas et al., 2003).

Based on this literature review, we propose the following guideline regarding feedback in classroom games:

The game must offer guidance, both for individual and collective action, through precise, timely and constant information regarding success and failure in performance.

The elements that favor interactivity are related to: participants' previous experience in the use of videogames (Orvis, Horn, & Belanich, 2008); students' motivation in having a concrete tool to participate in the events being carried out on screen (Infante, Hidalgo, Nussbaum, & Alarcón, 2009); the game's complexity taking into account the users' level of expertise (Sundar, Xu, & Bellur, 2010); and the teacher's development of class activities where he integrates teaching content with the students' participation in the videogame (Wilson, 2009).

These elements allow us to propose another guideline relating the kind of interaction players should have in classroom games:

The user's interaction with the game must be simple and intuitive and not add unnecessary complexity to the game.

Examples of commercial video games that correctly satisfy these guidelines are 'World of Warcraft' (Blizzard Entertainment, 2004), 'Diablo Series' (Blizzard Entertainment, 1996) and 'Metal Gear Series' (Konami, 1990).

2.3.1.2. Mechanics linked to learning objectives

It isn't enough to build a good game and add questions about certain content (Osterweil & Klopfer, 2009); it is fundamental that, through action and interaction in the context of the game, said content must be reinforced. The connection between ludic and instructional aspects of the game must be present throughout the duration. This promotes aspects such as attention, trust, satisfaction and discerning what is relevant, all of which characterize the intrinsic motivation linked to elements of the instructional or curricular process that the game covers (Cheng & Yeh, 2009). In this sense, the game presents itself, from beginning to end, as a situation that is uncovered through interactive action (Osterweil & Klopfer, 2009).

The importance of the intrinsic motivation provided by videogames lies in the stimulation of participants towards choosing tasks, regardless of their level of difficulty (Orvis et al., 2008), which presents an opportunity to create new learning strategies through quests (Dickey, 2007). There is great educational potential in living the events of a story through the game, since it leads participants to make decisions and understand complex phenomena (Aldinger et al., 2005) as well as triggering a metacognitive awareness of the learning process (Ke, 2008b). The interface must inform players of their options, integrating both curricular and ludic elements (Amory, 2007).

As is said by Gee (2005), good games present activities that are feasible yet challenging, thus ensuring that the frustration of potential failure does not take away from the pleasure of participating in the activity. The combination of teaching contents with the participants' direct experience favors learning based on problem resolution (Sancho et al., 2009) and the structured interaction between participants through a design that centers on educational objectives (Dillenbourg, 2002). In the same way, it allows the determining of class activities and contents that are to be evaluated (Cox & Marshall, 2007).

Based on this literature review, we propose the following guideline that links the game mechanics with the educational objectives:

The curricular content must be embedded in the game's functioning mechanics in such a way that the game's success is conditional to understanding its content.

Examples of commercial video games that correctly satisfy these guidelines are 'Age of Empires Series' (Microsoft, 1997), 'Total War Series' (The Creative Assembly, 2000) and 'Civilization Series' (Sid Meiers, 1991).

2.3.2. Game progression

These are guidelines that indicate how the game should evolve, as the players progress, considering mechanical, narrative and curricular aspects. Game progression guidelines answer the question: how should the game evolve?

2.3.2.1. Clear narrative

Games should be linked to a narrative or literary script that gives continuity to its activities. The narrative organizes and defines activities in a sequential and precise pattern, where the interface elements are joined as a whole, promoting immersion (Amory, 2007). It should be made up of quests and challenges in such a way that by solving them, the game is solved in a logical chain of events (Dickey, 2006; Lim, 2008), that favor the participants' commitment to the different path the game proposes (Dickey, 2007). The clarity of the narrative sequence allows the construction of hypotheses and strategies, and also gives contextual meaning to the elements of the virtual world (Gee, 2005), thus helping to synchronize actions between players (Zagal et al., 2000). Based on these elements, we propose a guideline that characterizes the narrative of classroom games:

The narrative should be composed of quests and challenges that define collaborative activities in a sequential and precise pattern.

The narrative flow incorporates participants' actions in the game and affects future actions (Martínez Ortiz, Moreno-Ger, Sierra, & Fernández Manjón, 2008). In this sense, the narrative should be linked to the achievement of instructional goals because this helps predefine possible actions in the narrative flow, as well as determining how long the game will last (Aldinger et al., 2005). On the other hand, the narrative structure must preserve the interactivity inherent in videogames in order to guarantee entertainment and learning (Moreno Ger et al., 2008). It is important for the design structure of the game to have a base story that allows participant immersion, elements of intrigue and emotional closeness which, as a whole, promote progressive interest in the activity (Orvis et al., 2008). A compelling narrative can provide an external motivation that the materials themselves may not be able to provide.

The role of the story in classroom games can be summarized in the following guideline:

The game must have a base story that allows the participants' immersion.

Examples of commercial video games that correctly satisfy these guidelines are 'Final Fantasy Series' (Square Co., 2001) and 'Baldur's Gate Series' (Bioware, 1998).

2.3.2.2. Gradual increase in difficulty

In education, teaching contents are organized into goals that favor students' gradual learning, which implies organizing learning activities in an ascending order of cognitive complexity (Anderson et al., 2001). In this sense, the educational videogame must have a script with a complexity structure associated to instructional strategies (Dillenbourg, 2002). This allows the definition of situations with different and progressive levels of difficulty, which maintain students' motivation to develop a certain ability or knowledge (Piirainen Marsh & Tainio, 2009; Infante & Nussbaum, 2010).

The importance of a script can be summarized in the following guideline:

The videogame must have a script with a complexity structure associated to instructional strategies.

Educational videogames use fantasy and entertainment as resources to develop problem solving hypotheses and strategies (Sancho et al., 2009; Rosas et al., 2003). The gradual increase in difficulty is expressed through the flow: challenge, puzzlement, and search offered by games to participants, promoting learning through the movement of abilities and knowledge (Amory, 2007), and which can be controlled by built-in assessment (Moreno & Mayer, 2010).

The link between game progression and learning progression is summarized in the following guideline:

The learning progression needs to be reflected by the instructional strategy and the difficulty progression in the game.

Examples of commercial video games that correctly satisfy these guidelines are 'Neverwinter Knights' (Bioware, 2002) and 'Resident Evil Series' (Capcom, 1996).

2.3.3. Methodology

This category covers the instructional aspects of class organization and guides the teacher's actions as game mediator. The methodology-related guidelines answer the question: how does the game help the instructional strategy?

2.3.3.1. The teacher is a mediator during the game

The teacher must ensure that the game helps his/her instructional strategy. Videogames are an element that favor the 'teacher effect' in students' learning (Annetta, Minogue, Holmes, & Cheng, 2009). The teacher leads the educational process in the classroom and is in charge of filling the gaps that exist between the students and the game, promoting discussion and reflection on contents (Moreno Ger et al., 2008). This means that the game's design must have a flexible structure that allows the teacher to guide the flow of the game to specific situations in the classroom (Aldinger et al., 2005; Wilson, 2009; Infante & Nussbaum, 2010), thus enriching his or her teaching practice (Cuban, Kirkpatrick & Peck, 2001).

When taking charge of integrating the instructional activity with the elements of the game, the teacher can design methods that include his or her students' variety of interests and cognitive needs (Virvou et al., 2005; Cox & Marshall, 2007; Infante & Nussbaum, 2010) that are relevant to the classroom context, through face to face interaction, which the structure of an isolated script cannot offer (Dillenbourg, 2002). In this sense, videogames do not guarantee learning unless they have the teacher as a main guide to the students' cognitive development (Ke, 2008a).

Based on this literature analysis, we propose a guideline to define how to design games according to the teacher's needs:

The game's design must have a flexible structure that enables the teacher, who is the game moderator and guides the flow of actions, to adjust the game to the actual participation of the students in the classroom.

Examples of commercial video games where these guidelines appear explicitly are those games that have a Game Master, which mediates between the game and the players, for example 'Dungeons and Dragons'(Wizards of the coast, 1997).

2.3.4. Collaboration

This category refers to interaction, both amongst participants, and between participants and the game. The use of the CMPG diversifies communication channels between the teacher and his or her students, as well as those among the students, to collaboratively solve the quests presented by the game. The guidelines of this category answer the question: how can teamwork between the game's participants be improved?

2.3.4.1. Organize face to face interaction

Face to face interaction is an everyday occurrence in the classroom, but its educational value has yet to be considered in traditional teaching methods. The use of technological resources allows students to have more options for participation and interaction (Gee, 2005). It is possible to incorporate face to face interaction into the design of game scripts (Dillenbourg, 2002). By combining technological resources with content transmission and dialogue amongst students, collaboration is promoted (Wilson, 2009; Susaeta et al., 2009), as is the case with simulation games that encourage the student to have a perspective of the game that considers other points of view (Chen, Lien, Annetta, & Lu, 2010).

In this sense, the game must allow face to face interaction between players, so that collaboration can happen. Although videogames don't replace the communicational richness of face to face interaction (Dillenbourg, 2002; Sancho et al., 2009), they generate conditions that allow it to take place, without restricting the students' movement within the classroom (Cortez et al., 2009), and even favoring direct participation of students on a single screen, through individual input devices (mouse) (Infante et al., 2009; Susaeta et al., 2009).

The back story and scene cuts in the game favor the teacher's mediation to promote direct communication amongst students (Dickey, 2006) in order to solve quests, where dialogue, as well as design and application of strategies, are key to the learning activity (Lim, 2008). The results of participation in the videogame, for example in simulated participation, guide the face- to face dialogue that allows learning to take place (Delwiche, 2006; Wilson, 2009). Computer technology can structure the dialogue in the classroom, to promote the making of collaborative decisions (Cortez et al, 2009; Infante et al., 2009).

The previous analysis results in the following proposed guideline:

The game must use elements such as the underlying story and scene cuts to favor the teacher's mediation and promote communication between students.

2.3.4.2. Mechanics linked to collaboration

Videogames promote and offer new resources for collaboration amongst students for a number of means: developing narrative abilities through the interactive construction of stories (Carbonaro et al., 2008); experiencing a role through which they can interact in the virtual world in order to achieve a certain goal (Aldinger et al., 2005); developing the practice of argumentative dialogue through the use of digital resources (Ravenscroft, 2007); and applying the information needed to solve a task in coordination with their peers (Hamalainen, 2008). The videogame can adapt to the students' different learning rhythms, because it offers an environment of dialogue with the game and among students (Virvou et al, 2005).

In educational videogames, the structure of the game must be related to the collaborative instructional strategy in a way that offers enough elements to stimulate fantasy, exploration and teamwork amongst players (Gee, 2005; Amory, 2007). Designing puzzles with a common goal for all players promotes the development of strategies and helpful relationships (El Nasr, Aghabeigi, Milam, Erfani, Lameman, Maygoli, & Mah, 2010). An unnecessarily complex interface, with unfamiliar participation tools, reduces the game's accessibility (Delwiche, 2006).

A complementary element that adds to the collaborative mechanics in each step of the game is the action guide, where the different collaborative options that allow students to solve the problem at hand are specified (Dillenbourg, 2002), thus promoting autonomy and individual responsibility in teamwork throughout the activity.

Regarding collaboration and games, we propose the following guideline:

Collaboration must be embedded in the game's functioning mechanics, so that its success is conditional to having worked collaboratively.

2.3.5. On screen information

Considering that the interface in computer mediums diversifies the users' interactivity and learning experience, (Sundar, Xu, & Bellur, 2010) in this section we considered guidelines that show how to display all the elements of the game in such a way as to reduce the students' cognitive load. The guidelines associated with this category respond to the question: how should the game look?

2.3.5.1. Adequate spatial distribution

Adequate spatial distribution means presenting static and dynamic elements on screen in such a way as to favor interactivity, meaning reciprocal actions between the student and the multimedia system (Domagk, Schwartz, & Plass, 2010). Videogames have evolved from simple two-dimensional games to advanced multiplayer three-dimensional experiences, thus better capturing the students' attention and allowing for more exploration of the virtual world (Lim, 2008). At the same time, the number of elements that exist in the virtual world has increased, making their correct placement more complex. In this sense, an appropriate stage design or distribution of elements on the screen favors aspects such as: playability (Fabricatore, Nussbaum, & Rosas, 2002), immersion (Dede, 2009), and the interaction between elements in the virtual world and its connection to the real world (Hinske, Langheinrich, & Lampe, 2008). It also complements verbal communication, favoring conversation that is functional to the activity, cooperation between players (Greiffenhagen & Watson, 2009), and the construction of individual knowledge sustained by collaboration (Looi & Chen, 2010).

Based on this analysis of spatial distribution, we propose two guidelines:

The system must distribute characters and activities around the map so as to take advantage of the available space.

Spatial distribution should correctly relate aspects of the embedded knowledge to its connection with the real world.

In difference to Massive Multiplayer Online Games (MMOGs), where each user begins the activity in the center of his individual screen (Delwiche, 2006), in CMPGs all participants share the same screen (Susaeta et al., 2009), making it necessary to use a stage design that uses the available space appropriately. This is facilitated by use of the camera, which allows the field of observation to be changed, thus favoring players' interdependence (Fabricatore et al., 2002). The shared visual space is useful in reaching collaborative solutions to visually complex tasks, complementing verbal communication between participants to describe the virtual environment (Gergle, Kraut, & Fussell, 2004).

Regarding the specific difficulties of CMPGs and space, we propose the following guideline:

The system must relate camera control to the interaction of the characters on the screen, so as to favor players' interdependence and the exploration of the virtual world when appropriate.

Examples of commercial video games that correctly satisfy these guidelines are 'Super Smash Brothers Brawl' (Nintendo, 2008) and 'Sims Series' (Electronic Arts, 1997).

2.3.5.2. Recognizable elements

In CMPGs, playing time is adjusted to the classroom time available (Susaeta et al., 2009); in this sense, it is necessary for characters and elements on screen to have distinctive traits that stand out (color, shape and action) allowing for quick recognition and differentiation between them (Cheng & Yeh, 2009), thus boosting learning and playability (Sundar, Xu, & Bellur, 2010). Emotional proximity between the player and his/her character improves when the player has the possibility to choose his or her character's distinctive traits. This improves teamwork as well as discerning actions in the game according to role (Dickey, 2007), which supports the fantasy of the game (Amory, 2007; Hinske et al., 2008). A clear distinction of the elements on the screen allows a delimitation of the quests, linking the narrative structure with the elements that compose, characterize and differentiate the many scenes of the virtual world (Lim, 2008). Additionally, adequate design of on screen elements and character animation stimulates positive emotions in players (El-Nasr, M., Aghabeigi, B., Milam, D., Erfani, M., Lameman, B., Maygoli, H., & Mah, S., 2010). The use of a large screen improves element recognition and the participants immersion in the virtual world (Bao & Gergle, 2009). The appropriate use of the entire screen improves video spatial abilities of diverging or multiple attention (Greenfield, 2009). This is aided by the three-dimensional design of the images and their relevance to the players' culture, which improves subjective immersion in the game (Dede, 2009).

Regarding character design, we present the following guideline:

Characters and elements on the screen must have distinctive traits that capture the players' attention (color, shape, and action).

Examples of commercial video games that correctly satisfy this guideline are 'Super Smash Brothers Brawl' (Nintendo, 2008) and 'Sims Series' (Electronic Arts, 1997).

2.3.5.3. Accessible language

The clarity of the language of the texts on screen, adjusted to the needs of the players, is related to a logical thinking structure which encourages the construction of problem solving hypotheses in players (Gee, 2005). Experiences developed to stimulate abilities for interactively building stories using computational tools in children (Carbonaro et al., 2008) indicate that it is possible to design a game with a grammatical structure that includes all participants. Also, narration that is simultaneous with the images on the screen is a form of multimedia activity that favors integration of information and learning (Moreno & Mayer 2000), while at the same time controlling the cognitive load by maintaining coherence between the visual and verbal information presented to the user (Plass, Moreno, & Brünken, 2010).

The structure of the text and the number of words affect reading time (Yan & Tourangeau, 2008). The average number of words a person can retain in an experimental situation is seventeen (Capner, Scarcia, & Graham, 2007), and the comprehensive reading of an item is linked to an average length of fifteen words (Velez & Ashworth, 2007). Additionally, the text must support both the storyline and the player' motivation (Dickey, 2006), offering information that allows understanding of the meaning of the elements on screen, linked to the development of quests (Amory, 2007). In coherence with the images on screen, texts must orient students to carry out actions that allow effective coordination within the game (Susaeta et al., 2009).

Based on the previous analysis of textual and spoken language, we propose the following two guidelines:

The text on the screen must have a clear message, be concise and easy to read, facilitating the comprehension of the elements presented in the scene.

Spoken text should be preferred over written text because it induces less cognitive load.

Examples of commercial video games that correctly satisfy these guidelines are 'Final Fantasy X' (Square Co, 2001), 'Final Fantasy XIII' (Square Co., 2010) and Mass Effect 2 (Bioware, 2010).

2.3.5.4. Avoid information overload

Information overload dissipates players' attention in the game's activities (Susaeta, et al., 2010). When information is distributed in the available space, and graduated in time, interaction among participants improves (Moraveji, Inkpen, Cutrell & Balakrishnan, 2009). Text, animation and audio occupy the user's perceptual bandwidth; therefore the coordination of information mediums must be functional to the activity, in order to boost interactivity (Sundar, Xu, & Bellur, 2010). Emotional proximity between the participant and his/her character improves when the participant has the possibility to choose the character's traits; this boosts teamwork and allows distinction between the different roles in the game (Dickey, 2007). In the same sense, game entities, when distinguishable from different types of information in a visible place, allow players to see, remember and participate (Fabricatore et al., 2002).

Appropriate management of information in games (text, images, and sounds) within a learning context promotes relational thinking and helps avoid concentrating on isolated events or abilities (Gee, 2005). The shared visual space favors the resolution of tasks that are visually complex in their spatial relations when information feedback is organized, evident, and immediate (Gergle et al., 2004). The different sources of information, as a whole, allow the construction of the game's narrative structure, which in turn allows participants to define an action circuit (Amory, 2007). Systematic management of information also favors learning from a constructivist perspective, as it allows participants to design strategies in solving the problems proposed by the game (Ang, Avni, & Zaphiris, 2008).

Information overload can be managed by applying the following guideline:

Individual information must not stand in the way of collective information and must be relevant to the problem that needs to be solved.

Examples of commercial video games that correctly satisfy this guideline are 'Age of Empires Series' (Microsoft, 1997) and 'Starcraft Series' (Blizzard Entertainment, 1998).

2.3.6. Holism

This last category provides a final guideline that gives a holistic vision of the game as a whole, combining all the elements in the previous section to create a unified experience. The question asked with this final guideline is: how can a holistic experience that satisfies the ludic and instructional aspects of the game be created?

2.3.6.1. Action guide

This final guideline links all aspects of the game. The design is contained in a document that details the possible steps within the game and defines communication, both amongst players and between them and the game (Zagal et al., 2000). An action guide allows developers to specify all the necessary attributes for complete and consistent action within the game, incorporating instructional and technological aspects that add to the organization and evaluation of the sequence of activities (Martínez Ortiz et al., 2008; Moreno Ger et al., 2008).

An action guide should link and regulate different ludic, methodological and collaborative processes which operate simultaneously in the game (Hamalainen, 2008), so as to assure that the elements on screen are linked in a narrative that promotes immersion (Amory, 2007) and the learning of all students, above the competition between themselves (Gee, 2005). Scripts must have the flexibility to adjust the game to the reality of the classroom, both in the way that the game's quests are proposed (Lim, 2008) and in the design of content presentation (Chang et al., 2009).

The final guideline can be summarized as follows:

The game must have a systematic design that includes the educational and ludic aspects, through a script that specifies action sequences, possibilities for action, and events that might take place both in the virtual world and in the real world.

Games such as 'Dungeons and Dragons' (Wizards of The Coast, 1997) use different guides to establish the basis of the game, the roles of the players and mediator, the narrative, and the interaction between them.

Section 2.3.6.2 summarizes the guidelines, showing the associated problem that each one solves, and how they are classified according to the twelve categories.

2.3.6.2. Guidelines Summary

Game mechanics: how should the game be played?

1. Interactivity and guidance
   - The game must offer guidance, both for individual and collective action, through precise, timely and constant information regarding success and failure in performance.
   - The user's interaction with the game must be simple and intuitive and not add unnecessary complexity to the game.
2. Mechanics linked to learning objectives
   - The curricular content must be embedded in the game's functioning mechanics in such a way that the game's success is conditional to understanding its content.

Game progression: how should the game evolve?

3. Clear narrative
   - The game must have a base story that allows the participants' immersion.
   - The narrative should be composed of quests and challenges that define collaborative activities in a sequential and precise pattern.
4. Gradual increase in difficulty
   - The videogame must have a script with a complexity structure associated to instructional strategies.

- The learning progression needs to be reflected by the instructional strategy and the difficulty progression in the game.

Methodology: how does the game help the instructional strategy?

5. The teacher is a mediator during the game
   - The game's design must have a flexible structure that enables the teacher, who is the game moderator and guides the flow of actions, to adjust the game to the actual participation of the students in the classroom.

Collaboration: how can teamwork between the game's participants be improved?

6. Organize face to face interaction
   - The game must use elements such as the underlying story and scene cuts to favor the teacher's mediation and promote communication between students.
7. Mechanics linked to collaboration
   - Collaboration must be embedded in the game's functioning mechanics so that its success is conditional to having worked collaboratively.

On-screen information: how should the game look?

8. Adequate spatial distribution
   - The system must distribute characters and activities around the map so as to take advantage of the available space.
   - The system must relate camera control to the interaction of the characters on the screen, so as to favor players' interdependence and the exploration of the virtual world when appropriate.
   - Spatial distribution should correctly relate aspects of the embedded knowledge to its connection with the real world.
9. Recognizable elements

- Characters and elements on the screen must have distinctive traits that capture the players attention (color, shape, and action).

10. Accessible language
    - The text on the screen must have a clear message, be concise and easy to read, facilitating the comprehension of the elements presented in the scene.
    - Spoken text should be preferred over written text because it induces less cognitive load.
11. Avoid information overload
    - Individual information must not stand in the way of collective information and must be relevant to the problem that needs to be solved.

Holism: how can a holistic experience that satisfies the ludic and instructional aspects of the game be created?

12. Action guide
    - The game must have a systematic design that includes the educational and ludic aspects, through a script that specifies action sequences, possibilities for action, and events that might take place both in the virtual world and in the real world.

2.4. Experimental study with redesigned version of the CMPG

2.4.1. CMPG Redesign

Using the guidelines previously described (Section 2.3.6.2) a series of improvement activities were performed to the original ecology CMPG games. In order to prioritize the improvements in the game, the importance of each guideline for this particular game was analyzed, allowing us to categorize them into two groups: primary guidelines and secondary guidelines. This distinction was based on both the general importance of the guideline in defining the learning and game experience, and the specific improvements that were needed considering the problems originally detected.

2.4.1.1. Primary guidelines

(i) Action guide:

A major improvement to the design of the CMPG was the development of a script, where the presentation times for texts and events that the students see on screen are coordinated with feedback mechanisms for each quest, which are defined both for individual and collective actions. The goal of this script is to improve the game's coherence, expressed in the students' motivation to participate in the activity.

(ii) The teacher is a mediator during the game:

Another important problem in the original implementation was the inability of the teacher to control the flow of the game. After the game started, the teacher lost the focus of the students in the game and it was really hard to get it back. To solve this problem, the possibility of stopping the game was introduced so the teacher could control the flow and support the students' work. We explicitly designed two types of pauses: during the game (development pause, which can be one or many pauses), and at the end of the game (final pause). To improve student comprehension and participation in the activity, we specified guiding questions for development pauses with the goal of reinforcing specific game elements or concepts. Some of the guiding questions to stimulate the discussion between the teacher and students were: Why is there an alert message on the screen? What can each student do to solve this situation as a group? What are we asking from our classmates? In the final pause, we aimed to favor the metacognition of the work carried out, expressing what was learned from the experience. The facilitating questions were: Why did we win/lose the game? What characterizes the elements? What explains the elements' behavior? What individual or collective actions explain the final result?

(iii) Mechanics linked to learning objectives:

To improve learning, explicit game rules were designed which tell players what can and cannot be done to win the game. These rules are directly related to the learning objectives, forcing the students to advance in the game only when they understand the specific objective. The rules were presented explicitly at the beginning, and throughout the game, showing on the screen individual and collective actions necessary in order to proceed. There were rules to hunt, plant, harvest, etc., as well as general instructions, such as 'do not kill all herbivores'. These explicit rules helped to reinforce both the goals in the game and the learning objectives of the class.

(iv) Gradual increase in difficulty:

In the original game the complexity of the game didn't allow the students to complete all the quests, which directly impacted on the learning objectives. To solve this issue, a simpler food chain was developed that adjusts the conceptual complexity of the quests as follows: Quest 1: getting to know the virtual world through collective actions and interaction with the plants; Quest 2: interaction with herbivores; Quest 3: interaction with carnivores; Quest 4: interaction with carnivores through a collaborative strategy; Quest 5 and Quest 6: maintaining the balance of the entire food chain. Through each quest, the difficulty of both the players actions and the educational content is gradually increased; in Quest 1 players must try their individual abilities; in Quest 2 each player keeps carrying out individual actions, but with a global goal of maintaining the balance between plants and herbivores; in Quests 3 and 4 players must coordinate their individual abilities to hunt carnivores; finally, in Quests 5 and 6 players must coordinate all the characters' abilities to maintain the balance between all the elements of the chain.

2.4.1.2. Secondary guidelines

(i) Interactivity and guidance:

Alert messages were added to signal when the success of the quest was being jeopardized. Congratulatory messages were given when a quest was completed, or when a collaborative task was achieved. When a new scenario was shown it was also signaled. Whenever relevant to the game, messages about abilities and how to use them appeared constantly in every quest.

The addition of an experience bar to show points for favorable individual actions was considered, however, this was not carried out, as the curricular time allotted to the game is brief. In this way we avoided excessive information, as well as feedback mechanisms that require a learning period exceeding the available time.

(ii) Clear narrative:

A base story was presented from the beginning of the game, explaining how the characters were part of it. Videos depicting the story were used, with the goal of achieving immersion in the game. Quests and challenges were relevant to the task of balancing the food chain and were coherent with the base story.

(iii) Organize face to face interaction:

Participants were distributed throughout the classroom in such a way that they were all visible to each other and everyone could see the screen (Figure 2.1). This favored collaboration within the game. In addition to the development and final pauses, which are also an opportunity for collaborative dialogues, other pauses were implemented before students began a quest (initial pause), which gave them 3 minutes to discuss and design collaborative strategies.

(iv) Mechanics linked to collaboration:

Interdependence between players was boosted with implicit rules. These rules are discovered by comparing actions between participants. They were not necessary in order to win the game, but they improved the players' efficiency and maintained motivation to participate in a virtual world where there were things to discover. An example of an implicit guideline was the fact that the hunter could carry seeds faster than the Shaman, which could be used to optimize the gameplay if players discovered this rule and coordinated their work.

(v) Adequate spatial distribution:

To improve the spatial distribution, from the beginning of each quest, characters and events were distributed throughout the entire screen. Additionally, a new camera control was implemented, performing zooms in−out as characters got closer/farther away on the screen, promoting virtual world exploration.

(vi) Recognizable elements:

The difference between the characters (Shaman and Hunter) was accentuated, and participants could choose their character's hair color, promoting recognition and identification. Additionally, each character action was animated. Regarding the rest of the game elements, specific shapes and colors were used to improve recognition of the plants, animals and seeds.

(vii) Accessible language:

The texts used in the game were redefined, changing for brief texts, with a maximum of 15 words each and containing only information relevant to the current activity. The exposure time of the text on screen was calibrated to be appropriate to the students' reading speed. When the instructions were presented, the game was paused and the teacher read the text on the screen to favor integration of visual and verbal information.

(viii) Avoid information overload:

Individual information (Life, Energy and Hunger) was reduced and reorganized, placed at the top and bottom of the screen, next to the character's face. Only the character's name was placed closed to him or her. Iconic figures were used to inform about individual actions, for example, feeding.

2.4.2. Experimental study

A field study was performed in order to observe whether or not the modifications made according to the design guidelines helped to solve the initial problems. Participants in this research were twenty 11 to 13 year old students from the 6th grade (where the food chain is studied) of an elementary school in Santiago, Chile. The school had similar socio economic characteristics to the school where the exploratory study was performed. The study was performed in two sessions, each one with 10 students because of the limitations of simultaneous players in the game (Figure 2.1). One of the researchers acted as teacher during both sessions.

To measure whether or not the design guidelines helped to solve the initial problems, we developed a scale of dichotomic observations in order to mark 'presence/no presence' of behaviors in participants that relate to the initial problems observed (Appendix A). For each problem, one or more observations were considered as indicators of it being solved. The observations were made for every quest of the game session, marking for each student whether or not the specific behavior described by the observation was present. The percentage of students that showed the behavior of all the observations related to each problem was used as a metric to show how well each guideline helped addressing its related problem.

To analyze the observations, the sessions were filmed with three cameras that recorded the participants' behavior in the classroom and on screen. Observation points were validated by agreement between three observers. For this study, we only took into consideration observations where the concordance index was greater than 0.75 calculated through the accordance ratio of the observers; all other observations were eliminated from the study. The final scale had 24 (out of a total of 32) observations, with a global concordance of 0.92.

In addition to these observations, we performed pre- and post-tests in order to validate that the students learned using the game. To assess the students learning, we designed an instrument called Evaluation Test on *Notions of Food Chain Balance* (NFCB), composed of 20 items with multiple-choice answers; designed according to the curricular program (MINEDUC, 2004). This test was examined and approved by three teachers who are experts in this area of the school curriculum. The analysis of the instrument's reliability and difficulty was done through the application of a test to 20 students of a similar age and educational level as those that comprised the study group. Cronbach's Alpha reliability was 0.74. The difficulty of the test was analyzed with a scale that produced scores that ranged from 0.05 (*very difficult*) to 0.99 (*very easy*). The result was 0.46, calculated as the proportion of people who correctly answered the test items, which indicates that the test is of intermediate difficulty.

2.4.3. Results and Discussions

Using the results of the dichotomic observations (Appendix A) for every student, we calculated the percentage of students who didn't experience each problem (Table 2.1). The results show that more than 80% of the participants didn't have problems with on-screen information (problems 8 to 11), and they didn't experience a lack of coordination between all the aspects of the game (problem 12). However, other problems didn't show this level of improvement. For example, only 32% of the students showed signs of a clear relation between game actions and learning contents (problem 2).

TABLE 2.1. Percentage of students who didn't experience each of the problems.

N	Problems	% Students who didn't experience the problem
1	Lack of feedback and guidance	50%
2	Unclear relation between game actions and learning content	32%
3	Unclear and weak narrative	72%
4	Too many concepts presented simultaneously	43%
5	The teacher role in the game was not clearly defined	58%
6	Lack of face to face interaction	43%
7	Lack of collaborative game mechanics	49%
8	Poor use of screen space	83%
9	Unrecognizable elements	87%
10	Inaccessible language	89%
11	Information overload	86%
12	Lack of coordination between all the aspects of the game	92%

A more detailed analysis was performed for problems 1 to 7, measuring for each quest of the game the percentage of the students who didn't have each problem. The 6 quests of the game were:

(i) Move as a group, plant greenery.

(ii) Hunt herbivore, feed character.

(iii) Move as a group, hunt carnivore without previous strategy.

(iv) Design strategy to hunt carnivore using strategy.

(v) Keep balance, first attempt.

(vi) Keep balance, second attempt.

As Table 2.2 illustrates, when closely observing these results, we can see that for problems 1 to 7 the percentage of students with the problem changes drastically from quest to quest. For example, for Quest 2, more than 70% of the students didn't show signs of lack of feedback and guidance (problem N° 1), unclear narrative (problem N° 3) and unclear role of the teacher (problem N° 5), but in Quest 3, where the solution requires a group strategy, these percentages fall. We can also see that, in general, the presence of problems decreases as of Quest 4. This is especially true for problem N° 2 (unclear relation between game actions and learning content) and N° 7 (lack of collaborative game mechanics), where students must work collaboratively in order to achieve goals. The increase of problem N° 5 (the teacher role in the game was not clearly defined) in Quest 6 is linked to an increase in the participants' autonomy for teamwork and greater mastery of the game. Finally, problem N° 4 (too many concepts presented simultaneously) and N° 2 (unclear relation between game actions and learning content), were not relevant in the initial sequences of the game (Quests 1 and 2) because participants interact with the screen and the teacher individually, in order to understand the elements of the game and their characters' attributes. But as of Quest 4, where a collaborative use of attributes is required, the number of students with these problems decreases progressively.

The degree to which a specific problem was solved can be interpreted as a measure of how helpful the design improvements, related to the specific guidelines, were. The four primary guidelines considered for the game redesign were linked to problems 2, 4, 5 and 12. Of these guidelines, only the *Action guide* guideline can be seen to have successfully helped in solving the original problems. The fact that, even in the final quest, 30% of students showed unclear relation between game actions and learning content, suggest that the redesigns performed following the *Mechanics linked to content* guideline were not enough. In some quests, the clarity and impact of the role of teacher was low, and too many concepts were presented simultaneously, suggesting that the design changes related to both *The teacher is a mediator* and *Gradual increase in difficulty* guidelines were not effective for every quest.

TABLE 2.2. Percentage of students without problems 1 to 7 on the specific quests.

N	Problems	Quest 1	Quest 2	Quest 3	Quest 4	Quest 5	Quest 6
1	Lack of feedback and guidance	0,20	0,78	0,53	0,40	0,43	0,65
2	Unclear relation between game actions and learning content	NA	NA	0,16	0,49	0,59	0,70
3	Unclear and weak narrative	0,71	0,70	0,59	0,81	0,82	0,80
4	Too many concepts presented simultaneously	NA	NA	0,15	0,70	0,80	0,93
5	The teacher role in the game was not clearly defined	0,38	0,75	0,48	0,75	0,75	0,38
6	Lack of face to face interaction	0,35	0,49	0,40	0,56	0,60	0,55
7	Lack of collaborative game mechanics	0,35	0,44	0,36	0,65	0,68	0,69

Most secondary guidelines achieved a good result in solving the original problem. The main reason for this is that, although the redesign aspects of these guidelines were not prioritized as high as the one of the primary guidelines, most of the changes needed to improve the CMPG were small and easy to implement, and the problems themselves were simple. The problems related to the primary guidelines, however, were more complex, involving the interplay of many elements during the session.

The results of the pre/post-test experiment showed that scores obtained on the NFCB test are higher in the post-test, with statistically significant differences ($p < 0.001$) and medium effect (Cohen's $d = 0,51$). The gender analysis showed that this result is present both in boys and girls, as can be seen in Table 2.3.

TABLE 2.3. Comparison of pre and post test by gender

		Mean	**Standard deviation**	**T**	**Significance**	**Cohen's d**
Boys	Pre Test	9,62	2,71	3,13	0,005	0,5
	Post Test	11,10	3,34			Medium
Girls	Pre Test	9,05	2,34	2,08	0,051	0,55
	Post Test	10,32	2,38			Medium

2.5. Conclusions

The main contribution of this work is the definition of a set of guidelines that help the design of CMPGs. These guidelines were proven to be useful in general when redesigning a game to solve its original problems, which was shown both by the results of the observations made of the activity and also by the learning results measured with the pre-post experimental design. The goal of any educational game is to improve the learning of the students, and the results obtained in this work suggest that the use of the design guidelines helped to achieve this goal. While primary guidelines, defined by their importance in defining the learning and game experience, convey different elements making the corresponding problems hard to solve, most secondary guidelines solved the diagnosed problems.

There are additional valuable lessons which were obtained from this experience. Although the design guidelines can be seen as general principles necessary to be considered in this kind of game, the detailed analysis made for each quest shows that in some circumstances some guidelines could be left aside, and in other moments they may even be contradictory. For example, the initial quests, which are focused on teaching the game, could limit some collaborative mechanics in order to ease the learning process. Also, in the final quests, where the students are mastering the game, the teacher may take a more secondary role and decrease his/her interventions in order to maximize the engagement of the class with the game. This suggests that the importance of some guidelines varies throughout the game, and this must be considered in order to make more informed design decisions.

The set of guidelines presented here are clearly not complete, but they present a step in defining principles that can guide the design process of CMPGs. Some of the guidelines can be considered as basic interface design principles (i.e., on-screen information guidelines), but we still considered it relevant to include them here, and restate their importance for this type of game. As future work, we would like to explore in more detail how these guidelines (and possibly additional ones) can be best used in different moments of the game, which would help to decide when a specific guideline must be applied and when it may be optional.

The implementation of videogames in the classroom has a level of effectiveness and results that depend on design (Amory, 2007). We must take into account that the game's mechanics are the first barrier in learning the contents provided by the CMPG. This is why, in a preliminary study, we considered that the use of a videogame in the classroom requires one session to master the game and another to use it in the learning process (Susaeta, Jimenez, Nussbaum, Gajardo, Andreu, & Villalta 2010). However, this study demonstrated that, if the CMPGs design doesn't carry the information load that is typical in online games, and maintains its ludic properties, it allows players to learn its mechanics and components in a few minutes, allowing the game to be used as an educational tool in one session.

The design guidelines presented here can be complemented with additional methods and guidelines for the curricular integration of contents and quests. For example, Bloom's revised taxonomy (Anderson et al., 2001) has been used as a design guide for defining the learning objectives and, based on those objectives, specifying the quests (Echeverría et al., 2011). The combination of these guidelines is something we plan to study further, in order to understand how they can be used together to create better educational games for the classroom.

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APPENDIX A. SCALE OF DICHOTOMIC OBSERVATIONS

Dichotomic observations used to measure how well the different problems of the original games were resolved in the redesigned version. In the table under Observation we indicate the expected outcome and under Associated Problems the original problems detected.

TABLE A.1. Dichotomic observations 1.

	Observation	Associated problems
1	More than half of the characters are not grouped in one specific sector of the screen, while game events are happening in a different sector.	Poor use of screen space
2	Characters are participating in all of the game events, located in different parts of the map.	Poor use of screen space
3	The player recognizes his/her character on the screen.	Unrecognizable elements
4	The player identifies his/her role as Shaman or Hunter in the game.	Unrecognizable elements, Information overload.
5	The player actions are coherent with the current elements on screen.	Unrecognizable elements, Information overload.
6	The player actions are coherent with the current actions being made by elements on the screen.	Unrecognizable elements, Information overload.
7	The player keeps his/her focus on the screen when there text instructions are displayed.	Inaccessible language, Information overload.
8	The player actions are coherent with the instructions on screen.	Inaccessible language, Information overload.
9	The player performs the correct actions when feedback information changes (level of hunger, energy, life).	Lack of feedback and guidance
10	The player talks with other players about the story and game elements.	Unclear and weak narrative, Lack of collaborative game mechanics

TABLE A.2. Dichotomic observations 2.

	Observation	Associated problems
11	The interaction between the player and the rest of the characters is the most efficient in order to solve the quest (he or she takes part in two or three player activities with success)	Too many concepts presented simultaneously, Unclear relation between game actions and learning content, Lack of collaborative game mechanics
12	The player states his/her opinion during pauses or gameplay.	Unclear and weak narrative, Lack of face to face interaction, Unclear relation between game actions and learning content
13	The player suggests concrete actions to other players during pauses or gameplay.	Lack of face to face interaction, Lack of collaborative game mechanics
14	The player asks questions or gives support to other players during pauses or gameplay.	Lack of face to face interaction, Lack of collaborative game mechanics
15	The player is not disruptive during pauses or gameplay.	Lack of face to face interaction, Lack of collaborative game mechanics
16	The actions performed by the player relate to solving the quest are caused by a comment made by another player.	Lack of collaborative game mechanics
17	The actions performed by the player relate to solving the quest are caused by the players own initiative.	Lack of collaborative game mechanics

TABLE A.3. Dichotomic observations 3.

	Observation	Associated problems
18	The player performs actions related to solving the quest.	Lack of collaborative game mechanics
19	There was agreement between the players and the teacher as to the best strategy to use in solving the quest.	The teacher's role in the game was not clearly defined, Lack of face to face interaction, Lack of collaborative game mechanics
20	The player shows satisfaction about his role in the game (positive emotional expressions).	Unclear and weak narrative, Lack of coordination between all the aspects of the game
21	The player doesn't show insatisfaction about his role in the game (positive emotional expressions).	Unclear and weak narrative, Lack of coordination between all the aspects of the game
22	The player does not appears indifferent to the current events in the game.	Unclear and weak narrative, Lack of coordination between all the aspects of the game
23	The player shows that he learned the content during the game, making comments that suggest that he knows what to do and why he won or lost.	Unclear relation between game actions and learning content
24	The player does not appear confused.	Lack of coordination between all the aspects of the game.

APPENDIX B. DESIGN GUIDELINES FOR CLASSROOM MULTIPLAYER PRESENTIAL GAMES

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Design guidelines for Classroom Multiplayer Presential Games (CMPG)

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A B S T R A C T

In a Classroom Multiplayer Presential Game (CMPG) peers interact collaboratively with the virtual world and amongst themselves in a shared space. The design of this kind of game, however, is a complex process that must consider instruction strategies, methodology, usability and ludic aspects. This article's aim is to develop and systematize guidelines for the design of CMPGs. To develop these guidelines we used a three-step process: evaluating an initial implementation of a CMPG and finding its problems; defining guidelines that can help overcome these problems; and redesigning the game based on the guidelines before testing it in a real class scenario to assess how helpful the guidelines were in solving the initial problems.

From the initial evaluation of the game, we developed a series of guidelines to overcome the existing problems that can be classified into six categories: On-screen information, Game mechanics, Game progression, Methodology, Collaboration, and Holism. After redesigning the game with these guidelines we performed a field study to see the behavior of the new CMPG, where we measured how well the guidelines were applied in the game-play and the effectiveness in regard to the learning level reached by the students. Our results indicate that the guidelines are a valuable tool in the design of CMPGs that foster learning, which was shown both in the results of the observations and in the significant increase in learning. Although the design guidelines can be seen as general principles, we conclude that they have to be considered differently for different games, and that even during a specific game the importance of each guideline may vary throughout the different quests.

1. Introduction

Videogames present many possibilities for developing knowledge and improve teaching and learning practices in schools, especially those of a collaborative and cooperative nature (El-Nasr et al., 2010). Within their broad potential, what stands out the most is: increasing students' interest in learning, adapting to the user's tempo, improving and strengthening the acquisition of information and awakening and maintaining motivation (Mayo, 2009).

As Amory (2007) points out, designing videogames for education implies integrating instruction strategies and ludic activities, in benefit of certain educational goals. The absence of this integration is one of the factors that inhibit the use of videogames in the classroom (Baek, 2008). Instruction strategies refer to the development of methods that make the curriculum operative within the context of the game, favoring learning (Serin, Serin, & Saygılı, 2009). On the other hand, ludic dynamics refer to the mechanics of the game and a relation to the players that assures motivation and playability (Fabricatore, Nussbaum, & Rosas, 2002). There is also a correlation between videogames design patterns and the development of cooperative relationships among players (El-Nasr et al., 2010).

When linked to new teaching practices, videogames improve educational achievements in students that are usually excluded by traditional teaching methods (Virvou, Katsionis, & Manos, 2005). In particular, Massive Multiplayer Online Games - (MMOGs) develop a type of technology that increases interactivity and participation in the virtual worlds offered to the user. This is explained by these games' specific characteristics: the design of a fantastic atmosphere that favors the participant's immersion, interactivity among participants through the virtual world, and a story and script structured around challenges that develop critical thinking, teamwork and strategies for problem solving (Dickey, 2007).

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In MMOGs each player actively participates in the game from their own individual computer, connecting online with other players, with an administrator who is in charge of organizing the rules and making sure the game is playable. Since the rules, objectives, accessories and tools of the game are built by the designers (Zagal, Nussbaum, & Rosas, 2000), this active participation could encourage learning the rules of a specific area of scientific knowledge (Gee, 2005). The use of games has an important educational potential, both in and out of the classroom.

Within the classroom, videogames could be the answer to the education community's concerns. For teachers, they could become a valuable tool that incorporates collaborative work and technology (Alvarez, 2006). Videogames can be used to cover certain points in the curriculum, but they must be designed so as to maintain the fundamental characteristics of the act of playing: freedom to explore, freedom to make mistakes, freedom to experiment, and the possibility of building an identity (Osterweil & Klopfer, in press).

Efforts to bring videogame computer technology to the concrete experiences of the classroom have not been particularly successful. Many educational videogames are not engaging. They don't incorporate fun into learning, resulting in repetitive, poorly designed tasks that don't help students' progressive comprehension (Kirriemuir & McFarlane, 2004) and are centered on simple *"drill and practice"* models (Squire, 2003). Others get stuck on "edutainment", meaning focusing on the ludic aspect, and don't challenge students to develop hypotheses or problem solving strategies (Sancho, Fuentes-Fernandez, Gómez-Martín, & Fernandez-Manjón, 2009). The implementation of design guides that incorporate the requirements of both education and videogame design is still a pending task (Moreno-Ger, Burgos, Martinez-Ortiz, Sierra, & Fernandez-Manjon, 2008; Squire, 2003).

In order to take advantage of the great interactive, motivational and participatory potential of MMOGs, we have studied how to incorporate them into the classroom (Nussbaum et al., 2009; Susaeta et al., 2010). In our setup, the game is carried out on a screen which is projected at the front of the classroom, through which the students interact with the virtual world and amongst themselves in the shared space (Fig. 1). Each player has his own input device, which allows him or her to control his or her character within the game. Because the players are inside the classroom, we replaced the word "Massive" for "Classroom", and because they are all present in the same physical space, interacting in person, we substituted "Online" for "Presential", thus obtaining Classroom Multiplayer Presential Game (CMPG), where there is a link between the mechanics of the game and the teaching process. Just as there is a game master in MMOGs, in CMPGs the teacher plays the role of game mediator, with the educational contents laid out in the virtual world, as well as in the direct interaction amongst students.

This article's objective is to develop and systematize guidelines for the design of CMPGs that support teaching activities linked to curriculum contents in the classroom. To devise these guidelines we developed a three-step process. First, we evaluated a previous implementation of a CMPG to teach the concept of the food chain to 6th grade students, to detect its problems and weaknesses (Section 2). Second, based on the problems detected, we used existing literature in educational game development, educational multimedia activities and commercial game design to define a series of guidelines aimed to solve these problems (Section 3). In the third and final step, we applied these guidelines to redesign the CMPG and tested the new version of the game with a group of students, analyzing how useful the guidelines were in designing the new version of the game (Section 4).

2. Building a CMPG to teach the food chain to 6th grade students

2.1. Description of the game

The use of computer technology in the classroom has proven to be effective in achieving motivation (Ke, 2008b), collaboration (Cortez, Nussbaum, Woywood, & Aravena, 2009) and learning results (Carbonaro et al., 2008; Plass et al., 2010a; Zurita, Nussbaum, & Shaples, 2003). Two kinds of educational objectives can be reached: transverse, pertaining to the development of an ethic conscience, personal self-

Fig. 1. Position of the screen and participants inside the classroom.

affirmation and coexistence with others; and vertical, pertaining to the progressive grasp on the contents of the school curriculum (Ministerio de Educación, 2002).

The CMPG to teach the concept of the food chain (Susaeta et al., 2010) was included in the ecology curriculum unit. The game uses interactivity and immersion to boost the achievement of transverse and vertical goals in the school curriculum at 6th grade level (Ministerio de Educación, 2004). The specific objectives and expected learning outcomes of the game are shown in Table 1. The game was designed for ten concurrent players because this was experimentally shown to be the maximum number of avatars that can simultaneously play on one conventional screen (1.5 m $\times$ 1.5 m) (Susaeta et al., 2010).

The ecology game includes a number of different quests following the CMPG model (Echeverría et al., 2011), each one designed to emphasize a key teaching objective. They are arranged linearly so that the end of one marks the beginning of the next. This order is determined by the curriculum structure set by the Chilean Ministry of Education and ensures that the course concepts are delivered incrementally.

Students participated in the virtual world after choosing a character with specific abilities: “Shaman”, with the ability to cure diseases and plant seeds, or “Hunter”, with the ability to hunt. Students controlled their character by using the left and right buttons (one mouse per student).

Three of the game’s quests are aimed at achieving specific vertical objectives (Table 1). In the first quest, a new foreign species joins the ecosystem. This new predator starts feeding on the predators that were previously at the top of the food chain, transforming the ecosystem. The players must protect the ecosystem by scaring away the new species; to do this they must approach the new predator species in groups of no less than three players so as to lead it away from the playing zone.

In the second quest, a strange parasite starts to affect all the animals and it turns into an epidemic. The players have to contain this epidemic. To do this, two roles are defined in the game: the hunter, who paralyzes the infected animal, and the Shaman, who later cures it.

In the third quest, there is an explosive reproduction of the herbivorous population, becoming a risk to plant life. In the virtual setting, the plant ecosystem comprises three areas and its existence is at risk from this increase in herbivorous predators. The players must work together to prevent these herbivores from destroying the ecosystem by killing off plants in each one of these three zones. The players must plant more plants, kill the herbivores when they become too numerous and ensure that there are always carnivorous predators in each zone.

The game is used as a supporting tool by the teacher to conduct the class, who is in charge of the computer which was running the game. As the students advance in the game, the teacher can pause the game-play and use the whiteboard to explain a specific concept about the ecological balance that was observed in the game. The teacher also fulfills the role of mediator in the discussions between the students, relating the strategy to solve each quest and by guiding the students, when necessary, according to the teaching objectives.

2.2. *Exploratory study*

An exploratory study was conducted to understand how the players interacted with the game (Susaeta et al., 2010). The study involved ten 7th grade students, ages ranging from 12 to 14, in a in a regular middle socioeconomic status primary school of Santiago de Chile. In the study, one of the researchers acted as the teacher, guiding the students game sessions and mediating their interaction. The game was played in a traditional classroom, but the chairs were relocated to have the students closer to the screen and facing each other (Fig. 1).

The results of this study showed that the CMPG favored the achievement of vertical goals in students, improving the learning results of content relating to the food chain through the application of the corresponding contents to the virtual world offered by the game. With regard to transverse goals, promotion of responsibility, autonomy, reflection, and teamwork could be observed in students.

The methodology used to analyze the player’s experience with the game included both ethnographic observations during the game session and discussion with the students after the game was played. The qualitative observations were gathered by two researchers through the different quests of the game, and they were classified into two types: individual work and collaborative work observations. The individual work observations were focused on two dimensions: identification of elements in the game and activity understanding. The collaborative work observations were focused on four dimensions: exchange of information between players, negotiation, leadership and coordination.

The results of the observations made during the game session and the discussion with the students showed that the experience was not without difficulties, and that many aspects of the game could be improved. A careful review of this initial experimental study allowed us to identify a series of specific problems and weaknesses in the game:

1. *Lack of feedback and guidance:* There is feedback at the end of the quest, but not during the process. Because of this, players cannot tell which actions – whether individual or collective - are best for solving the activity. Players tend to forget, or mistake, their character’s abilities, lessening on-screen participation.
2. *Unclear relation between game actions and learning content*: Players lose the quests because they don’t understand the interdependence between the elements of the food chain.
3. *Unclear and weak narrative*: The game’s activities are not sustained, or don’t develop the motivational potential of the narrative.
4. *Too many concepts presented simultaneously*: Quests cover several food chain concepts simultaneously. This adds fantasy to the game, but makes the didactic presentation of the food chain difficult. Quest resolution demands collaborative actions with different levels of difficulty to be carried out.

Table 1
Teaching objectives of the ecology game.

Vertical teaching objectives	Transversal teaching objectives
To describe and comprehend the processes of flow and exchange of material and energy between living beings in a hypothetical ecosystem.	To promote collaboration, responsibility and personal autonomy. To use knowledge and be able to select relevant information. To promote initiative and teamwork

5. *The teacher role in the game was not clearly defined*: The absence of predefined criteria and guiding questions to support the teacher's role diminishes student participation.
6. *Lack of face to face interaction*: Players understand the quests and the fact that the solution requires direct dialogue between them. However, the game does not offer enough favorable conditions for a collaborative dialogue.
7. *Lack of collaborative game mechanics*: The learning of transverse goals was affected by the absence of collaborative mechanisms to be discovered in the game. Players with better videogame abilities may lose interest in a virtual world where they have nothing new to discover.
8. *Poor use of screen space*: At the beginning of the game, the characters and events are located on certain parts of the screen. This generates grouping and space misuse, creating confusion.
9. *Unrecognizable elements*: Participants mistake their characters during the game. The interaction between characters and the screen elements is not evident.
10. *Inaccessible language*: During the activity, students don't read the instructions on the screen. Texts are too long, and there are parallel activities on screen.
11. *Information overload*: The individual information surrounding each character confuses players when they interact.
12. *Lack of coordination between all the aspects of the game*: The ludic, instructional and collaborative dimensions of the game were not explicitly coordinated. This affected the integral comprehension of the game as a whole.

3. Guidelines for the design of a CMPG

For each of the problems described in Section 2.2, we propose a design guideline that helps to solve the specific difficulties associated with the problem. The guidelines we present in this section for the development of CMPGs consider two contributing factors: instruction strategies and game elements (Amory, 2007). The design guidelines are grouped in six categories: game mechanics, game progression, methodology, collaboration, on-screen information and holism.

3.1. Game mechanics

Game mechanics for learning describe patterns of behavior through which learners/players interact with and learn from the game, and are designed in pursuit of optimal insertion into a classroom context. In this sense, game mechanics guidelines answer the question: how should the game be played?

3.1.1. Interactivity and guidance

Considering that unguided discovery does not work, Domagk, Schwartz, and Plass (2010) propose a model for interactive multimedia learning, i.e. learning activities where the students interact using multiple media (visual, audio, etc.), an example of which are educational games. This model observes that interactivity refers to reciprocal activities among the action possibilities offered by the multimedia system, where action, motivation, and the student's cognitive processes are oriented towards achieving learning. Consequently, designing an educational game requires interactivity guides to orient the student's actions, which implies concepts such as feedback, notices and action suggestions that are specific to each student (Domagk et al., 2010).

Feedback is inherent in videogames; it maintains participation, and informs players of their achievement level (Aldinger, Kopf, Scheele, & Effelsberg, 2005; Ang, Avni, & Zaphiris, 2008; Moreno-Ger et al., 2008). If the game feedback is delivered in a constant manner throughout the game it can also work as reinforcement to participants' partial achievements (Osterweil & Klopfer, in press).

In collaborative games it is important to differentiate between two types of feedback: individual feedback, which is targeted to each individual player, and collective feedback, which is targeted to all the players, or a subgroup of players. Individual feedback promotes the experience of a role within the game (Lim, 2008), while collective feedback orients interaction between participants (Lim, 2008; Sancho et al., 2009). Feedback to individual and collective action is efficient when it is coherent with the game's design for the flow of activities (Dillenbourg, 2002). In other words, an appropriate design, which promotes learning, is achieved with precise, timely, and constant information regarding success and failure in the participants' performance (Rosas et al., 2003).

Based on this literature review, we propose the following guideline regarding feedback in classroom games:

- ➢ The game must offer guidance, both for individual and collective action, through precise, timely and constant information regarding success and failure in performance.

The elements that favor interactivity are related to: participants' previous experience in the use of videogames (Orvis, Horn, & Belanich, 2008); students' motivation in having a concrete tool to participate in the events being carried out on screen (Infante, Hidalgo, Nussbaum, & Alarcón, 2009); the game's complexity taking into account the users' level of expertise (Sundar, Xu, & Bellur, 2010); and the teacher's development of class activities where he integrates teaching content with the students' participation in the videogame (Wilson, 2009).

These elements allow us to propose another guideline relating the kind of interaction players should have in classroom games:

- ➢ The user's interaction with the game must be simple and intuitive and not add unnecessary complexity to the game.

Examples of commercial video games that correctly satisfy these guidelines are "World of Warcraft" (Blizzard Entertainment, 2004), "Diablo Series" (Blizzard Entertainment, 1996) and "Metal Gear Series" (Konami, 1990).

3.1.2. Mechanics linked to learning objectives

It isn't enough to build a good game and add questions about certain content (Osterweil & Klopfer, in press); it is fundamental that, through action and interaction in the context of the game, said content must be reinforced. The connection between ludic and instructional aspects of the game must be present throughout the duration. This promotes aspects such as attention, trust, satisfaction and discerning what is relevant, all of which characterize the intrinsic motivation linked to elements of the instructional or curricular process that the game covers (Cheng & Yeh, 2009). In this sense, the game presents itself, from beginning to end, as a situation that is uncovered through interactive action (Osterweil & Klopfer, in press).

The importance of the intrinsic motivation provided by videogames lies in the stimulation of participants towards choosing tasks, regardless of their level of difficulty (Orvis et al., 2008), which presents an opportunity to create new learning strategies through quests (Dickey, 2007). There is great educational potential in living the events of a story through the game, since it leads participants to make decisions and understand complex phenomena (Aldinger et al., 2005) as well as triggering a metacognitive awareness of the learning process (Ke, 2008b). The interface must inform players of their options, integrating both curricular and ludic elements (Amory, 2007).

As is said by Gee (2005), good games present activities that are feasible yet challenging, thus ensuring that the frustration of potential failure does not take away from the pleasure of participating in the activity. The combination of teaching contents with the participants' direct experience favors learning based on problem resolution (Sancho et al., 2009) and the structured interaction between participants through a design that centers on educational objectives (Dillenbourg, 2002). In the same way, it allows the determining of class activities and contents that are to be evaluated (Cox & Marshall, 2007).

Based on this literature review, we propose the following guideline that links the game mechanics with the educational objectives:

➢ The curricular content must be embedded in the game's functioning mechanics in such a way that the game's success is conditional to understanding its content.

Examples of commercial video games that correctly satisfy these guidelines are "Age of Empires Series" (Microsoft, 1997), "Total War Series" (The Creative Assembly, 2000) and "Civilization Series" (Sid Meiers, 1991).

3.2. *Game progression*

These are guidelines that indicate how the game should evolve, as the players progress, considering mechanical, narrative and curricular aspects. Game progression guidelines answer the question: how should the game evolve?

3.2.1. *Clear narrative*

Games should be linked to a narrative or literary script that gives continuity to its activities. The narrative organizes and defines activities in a sequential and precise pattern, where the interface elements are joined as a whole, promoting immersion (Amory, 2007). It should be made up of quests and challenges in such a way that by solving them, the game is solved in a logical chain of events (Dickey, 2006; Lim, 2008), that favor the participants' commitment to the different path the game proposes (Dickey, 2007). The clarity of the narrative sequence allows the construction of hypotheses and strategies, and also gives contextual meaning to the elements of the virtual world (Gee, 2005), thus helping to synchronize actions between players (Zagal et al., 2000).

Based on these elements, we propose a guideline that characterizes the narrative of classroom games:

➢ The narrative should be composed of quests and challenges that define collaborative activities in a sequential and precise pattern.

The narrative flow incorporates participants' actions in the game and affects future actions (Martínez-Ortiz, Moreno-Ger, Sierra, & Fernández-Manjón, 2008). In this sense, the narrative should be linked to the achievement of instructional goals because this helps predefine possible actions in the narrative flow, as well as determining how long the game will last (Aldinger et al., 2005). On the other hand, the narrative structure must preserve the interactivity inherent in videogames in order to guarantee entertainment and learning (Moreno-Ger et al., 2008). It is important for the design structure of the game to have a base story that allows participant immersion, elements of intrigue and emotional closeness which, as a whole, promote progressive interest in the activity (Orvis et al., 2008). A compelling narrative can provide an external motivation that the materials themselves may not be able to provide.

The role of the story in classroom games can be summarized in the following guideline:

➢ The game must have a base story that allows the participants' immersion.

Examples of commercial video games that correctly satisfy these guidelines are "Final Fantasy Series" (Square Co., 2001) and "Baldur's Gate Series" (Bioware, 1998).

3.2.2. *Gradual increase in difficulty*

In education, teaching contents are organized into goals that favor students' gradual learning, which implies organizing learning activities in an ascending order of cognitive complexity (Anderson et al., 2001). In this sense, the educational videogame must have a script with a complexity structure associated to instructional strategies (Dillenbourg, 2002). This allows the definition of situations with different and progressive levels of difficulty, which maintain students' motivation to develop a certain ability or knowledge (Infante & Nussbaum, 2010; Piirainen-Marsh & Tainio, 2009).

The importance of a script can be summarized in the following guideline:

➢ The videogame must have a script with a complexity structure associated to instructional strategies.

Educational videogames use fantasy and entertainment as resources to develop problem solving hypotheses and strategies (Rosas et al., 2003; Sancho et al., 2009). The gradual increase in difficulty is expressed through the flow: challenge, puzzlement, and search offered by games to participants, promoting learning through the movement of abilities and knowledge (Amory, 2007), and which can be controlled by built-in assessment (Moreno & Mayer, 2010).

The link between game progression and learning progression is summarized in the following guideline:

- The learning progression needs to be reflected by the instructional strategy and the difficulty progression in the game.

Examples of commercial video games that correctly satisfy these guidelines are "Neverwinter Knights" (Bioware, 2002) and "Resident Evil Series" (Capcom, 1996).

3.3. Methodology

This category covers the instructional aspects of class organization and guides the teacher's actions as game mediator. The methodology-related guidelines answer the question: how does the game help the instructional strategy?

3.3.1. The teacher is a mediator during the game

The teacher must ensure that the game helps his/her instructional strategy. Videogames are an element that favor the "teacher effect" in students' learning (Annetta, Minogue, Holmes, & Cheng, 2009). The teacher leads the educational process in the classroom and is in charge of filling the gaps that exist between the students and the game, promoting discussion and reflection on contents (Moreno-Ger et al., 2008). This means that the game's design must have a flexible structure that allows the teacher to guide the flow of the game to specific situations in the classroom (Aldinger et al., 2005; Infante & Nussbaum, submitted for publication; Wilson, 2009), thus enriching his/her teaching practice (Cuban, Kirkpatrick, & Peck, 2001).

When taking charge of integrating the instructional activity with the elements of the game, the teacher can design methods that include his/her students' variety of interests and cognitive needs (Cox & Marshall, 2007; Infante & Nussbaum, submitted for publication; Virvou et al., 2005) that are relevant to the classroom context, through face to face interaction, which the structure of an isolated script cannot offer (Dillenbourg, 2002). In this sense, videogames do not guarantee learning unless they have the teacher as a main guide to the students' cognitive development (Ke, 2008a).

Based on this literature analysis, we propose a guideline to define how to design games according to the teacher's needs:

- The game's design must have a flexible structure that enables the teacher, who is the game moderator and guides the flow of actions, to adjust the game to the actual participation of the students in the classroom.

Examples of commercial video games where these guidelines appear explicitly are those games that have a *Game Master*, which mediates between the game and the players, for example "Dungeons and Dragons"(Wizards of the coast, 1997).

3.4. Collaboration

This category refers to interaction, both amongst participants, and between participants and the game. The use of the CMPG diversifies communication channels between the teacher and his/her students, as well as those among the students, to collaboratively solve the quests presented by the game. The guidelines of this category answer the question: how can teamwork between the game's participants be improved?

3.4.1. Organize face to face interaction

Face to face interaction is an everyday occurrence in the classroom, but its educational value has yet to be considered in traditional teaching methods. The use of technological resources allows students to have more options for participation and interaction (Gee, 2005). It is possible to incorporate face to face interaction into the design of game scripts (Dillenbourg, 2002). By combining technological resources with content transmission and dialogue amongst students, collaboration is promoted (Wilson, 2009; Susaeta et al., 2009), as is the case with simulation games that encourage the student to have a perspective of the game that considers other points of view (Chen, Lien, Annetta, & Lu, 2010).

In this sense, the game must allow face to face interaction between players, so that collaboration can happen. Although videogames don't replace the communicational richness of face to face interaction (Dillenbourg, 2002; Sancho et al., 2009), they generate conditions that allow it to take place, without restricting the students' movement within the classroom (Cortez et al., 2009), and even favoring direct participation of students on a single screen, through individual input devices (mouse) (Infante et al., 2009; Susaeta et al., 2009).

The back story and scene cuts in the game favor the teacher's mediation to promote direct communication amongst students (Dickey, 2006) in order to solve quests, where dialogue, as well as design and application of strategies, are key to the learning activity (Lim, 2008). The results of participation in the videogame, for example in simulated participation, guide the face-to face dialogue that allows learning to take place (Delwiche, 2006; Wilson, 2009). Computer technology can structure the dialogue in the classroom, to promote the making of collaborative decisions (Cortez et al., 2009; Infante et al., 2009).

The previous analysis results in the following proposed guideline:

- The game must use elements such as the underlying story and scene cuts to favor the teacher's mediation and promote communication between students.

3.4.2. Mechanics linked to collaboration

Videogames promote and offer new resources for collaboration amongst students for a number of means: developing narrative abilities through the interactive construction of stories (Carbonaro et al., 2008); experiencing a role through which they can interact in the virtual world in order to achieve a certain goal (Aldinger et al., 2005); developing the practice of argumentative dialogue through the use of digital resources (Ravenscroft, 2007); and applying the information needed to solve a task in coordination with their peers (Hamalainen, 2008). The videogame can adapt to the students' different learning rhythms, because it offers an environment of dialogue with the game and among students (Virvou et al., 2005).

In educational videogames, the structure of the game must be related to the collaborative instructional strategy in a way that offers enough elements to stimulate fantasy, exploration and teamwork amongst players (Amory, 2007; Gee, 2005). Designing puzzles with a common goal for all players promotes the development of strategies and helpful relationships (El-Nasr et al., 2010). An unnecessarily complex interface, with unfamiliar participation tools, reduces the game's accessibility (Delwiche, 2006).

A complementary element that adds to the collaborative mechanics in each step of the game is the action guide, where the different collaborative options that allow students to solve the problem at hand are specified (Dillenbourg, 2002), thus promoting autonomy and individual responsibility in teamwork throughout the activity.

Regarding collaboration and games, we propose the following guideline:

- Collaboration must be embedded in the game's functioning mechanics, so that its success is conditional to having worked collaboratively.

3.5. On-screen information

Considering that the interface in computer mediums diversifies the users' interactivity and learning experience, (Sundar et al., 2010) in this section we considered guidelines that show how to display all the elements of the game in such a way as to reduce the students' cognitive load. The guidelines associated with this category respond to the question: how should the game look?

3.5.1. Adequate spatial distribution

Adequate spatial distribution means presenting static and dynamic elements on screen in such a way as to favor interactivity, meaning reciprocal actions between the student and the multimedia system (Domagk et al., 2010). Videogames have evolved from simple two-dimensional games to advanced multiplayer three-dimensional experiences, thus better capturing the students' attention and allowing for more exploration of the virtual world (Lim, 2008). At the same time, the number of elements that exist in the virtual world has increased, making their correct placement more complex. In this sense, an appropriate stage design or distribution of elements on the screen favors aspects such as: playability (Fabricatore et al., 2002), immersion (Dede, 2009), and the interaction between elements in the virtual world and its connection to the real world (Hinske, Langheinrich, & Lampe, 2008). It also complements verbal communication, favoring conversation that is functional to the activity, cooperation between players (Greiffenhagen & Watson, 2009), and the construction of individual knowledge sustained by collaboration (Looi & Chen, 2010).

Based on this analysis of spatial distribution, we propose two guidelines:

- The system must distribute characters and activities around the map so as to take advantage of the available space.
- Spatial distribution should correctly relate aspects of the embedded knowledge to its connection with the real world.

In difference to Massive Multiplayer Online Games (MMOGs), where each user begins the activity in the center of his individual screen (Delwiche, 2006), in CMPGs all participants share the same screen (Susaeta et al., 2009), making it necessary to use a stage design that uses the available space appropriately. This is facilitated by use of the camera, which allows the field of observation to be changed, thus favoring players' interdependence (Fabricatore et al., 2002). The shared visual space is useful in reaching collaborative solutions to visually complex tasks, complementing verbal communication between participants to describe the virtual environment (Gergle, Kraut, & Fussell, 2004).

Regarding the specific difficulties of CMPGs and space, we propose the following guideline:

- The system must relate camera control to the interaction of the characters on the screen, so as to favor players' interdependence and the exploration of the virtual world when appropriate.

Examples of commercial video games that correctly satisfy these guidelines are “Super Smash Brothers Brawl” (Nintendo, 2008) and “Sims Series” (Electronic Arts, 1997).

3.5.2. Recognizable elements

In CMPGs, playing time is adjusted to the classroom time available (Susaeta et al., 2010); in this sense, it is necessary for characters and elements on screen to have distinctive traits that stand out (color, shape and action) allowing for quick recognition and differentiation between them (Cheng & Yeh, 2009), thus boosting learning and playability (Sundar et al., 2010). Emotional proximity between the player and his/her character improves when the player has the possibility to choose his/her character's distinctive traits. This improves teamwork as well as discerning actions in the game according to role (Dickey, 2007), which supports the fantasy of the game (Amory, 2007; Hinske et al., 2008). A clear distinction of the elements on the screen allows a delimitation of the quests, linking the narrative structure with the elements that compose, characterize and differentiate the many scenes of the virtual world (Lim, 2008). Additionally, adequate design of on screen elements and character animation stimulates positive emotions in players (El-Nasr, M., Aghabeigi, B., Milam, D., Erfani, M., Lameman, B., Maygoli, H., & Mah, S., 2010).

The use of a large screen improves element recognition and the participants' immersion in the virtual world (Bao & Gergle, 2009). The appropriate use of the entire screen improves video-spatial abilities of diverging or multiple attention (Greenfield, 2009). This is aided by the three-dimensional design of the images and their relevance to the players' culture, which improves subjective immersion in the game (Dede, 2009).

Regarding character design, we present the following guideline:

- Characters and elements on the screen must have distinctive traits that capture the players' attention (color, shape, and action).

Examples of commercial video games that correctly satisfy this guideline are "Super Smash Brothers Brawl" (Nintendo, 2008) and "Sims Series" (Electronic Arts, 1997).

3.5.3. Accessible language

The clarity of the language of the texts on screen, adjusted to the needs of the players, is related to a logical thinking structure which encourages the construction of problem solving hypotheses in players (Gee, 2005). Experiences developed to stimulate abilities for interactively building stories using computational tools in children (Carbonaro et al., 2008) indicate that it is possible to design a game with a grammatical structure that includes all participants. Also, narration that is simultaneous with the images on the screen is a form of multimedia activity that favors integration of information and learning (Moreno & Mayer,, 2000), while at the same time controlling the cognitive load by maintaining coherence between the visual and verbal information presented to the user (Plass, Moreno, & Brünken, 2010).

The structure of the text and the number of words affect reading time (Yan & Tourangeau, 2008). The average number of words a person can retain in an experimental situation is seventeen (Capner, Scarcia, & Graham, 2007), and the comprehensive reading of an item is linked to an average length of fifteen words (Velez & Ashworth, 2007). Additionally, the text must support both the storyline and the players' motivation (Dickey, 2006), offering information that allows understanding of the meaning of the elements on screen, linked to the development of quests (Amory, 2007). In coherence with the images on screen, texts must orient students to carry out actions that allow effective coordination within the game (Susaeta et al., 2010).

Based on the previous analysis of textual and spoken language, we propose the following two guidelines:

- The text on the screen must have a clear message, be concise and easy to read, facilitating the comprehension of the elements presented in the scene.
- Spoken text should be preferred over written text because it induces less cognitive load (Mayer & Moreno, 2010).

Examples of commercial video games that correctly satisfy these guidelines are "Final Fantasy X" (Square Co, 2001), "Final Fantasy XIII" (Square Co., 2010) and Mass Effect 2 (Bioware, 2010).

3.5.4. Avoid information overload

Information overload dissipates players' attention in the game's activities (Susaeta et al., 2010). When information is distributed in the available space, and graduated in time, interaction among participants improves (Moraveji, Inkpen, Cutrell, & Balakrishnan, 2009). Text, animation and audio occupy the user's perceptual bandwidth; therefore the coordination of information mediums must be functional to the activity, in order to boost interactivity (Sundar et al., 2010). Emotional proximity between the participant and his/her character improves when the participant has the possibility to choose the character's traits; this boosts teamwork and allows distinction between the different roles in the game (Dickey, 2007). In the same sense, game entities, when distinguishable from different types of information in a visible place, allow players to see, remember and participate (Fabricatore et al., 2002).

Appropriate management of information in games (text, images, and sounds) within a learning context promotes relational thinking and helps avoid concentrating on isolated events or abilities (Gee, 2005). The shared visual space favors the resolution of tasks that are visually complex in their spatial relations when information feedback is organized, evident, and immediate (Gergle et al., 2004). The different sources of information, as a whole, allow the construction of the game's narrative structure, which in turn allows participants to define an action circuit (Amory, 2007). Systematic management of information also favors learning from a constructivist perspective, as it allows participants to design strategies in solving the problems proposed by the game (Ang et al., 2008).

Information overload can be managed by applying the following guideline:

- Individual information must not stand in the way of collective information and must be relevant to the problem that needs to be solved.

Examples of commercial video games that correctly satisfy this guideline are "Age of Empires Series" (Microsoft, 1997) and "Starcraft Series" (Blizzard Entertainment, 1998).

3.6. Holism

This last category provides a final guideline that gives a holistic vision of the game as a whole, combining all the elements in the previous section to create a unified experience. The question asked with this final guideline is: how can a holistic experience that satisfies the ludic and instructional aspects of the game be created?

3.6.1. Action guide

This final guideline links all aspects of the game. The design is contained in a document that details the possible steps within the game and defines communication, both amongst players and between them and the game (Zagal et al., 2000). An action guide allows developers to specify all the necessary attributes for complete and consistent action within the game, incorporating instructional and technological aspects that add to the organization and evaluation of the sequence of activities (Martínez-Ortiz et al., 2008; Moreno-Ger et al., 2008).

An action guide should link and regulate different ludic, methodological and collaborative processes which operate simultaneously in the game (Hamalainen, 2008), so as to assure that the elements on screen are linked in a narrative that promotes immersion (Amory, 2007) and the learning of all students, above the competition between themselves (Gee, 2005). Scripts must have the flexibility to adjust the game to the reality of the classroom, both in the way that the game's quests are proposed (Lim, 2008) and in the design of content presentation (Chang et al., 2009).

The final guideline can be summarized as follows:

- The game must have a systematic design that includes the educational and ludic aspects, through a script that specifies action sequences, possibilities for action, and events that might take place both in the virtual world and in the real world.

Games such as "Dungeons and Dragons" (Wizards of The Coast, 1997) use different guides to establish the basis of the game, the roles of the players and mediator, the narrative, and the interaction between them.

Table 2 summarizes the guidelines, showing the associated problem that each one solves, and how they are classified according to the twelve categories:

4. Experimental study with redesigned version of the CMPG

4.1. CMPG redesign

Using the guidelines previously described (Table 2) a series of improvement activities were performed to the original ecology CMPG games. In order to prioritize the improvements in the game, the importance of each guideline for this particular game was analyzed, allowing us to categorize them into two groups: primary guidelines and secondary guidelines. This distinction was based on both the general importance of the guideline in defining the learning and game experience, and the specific improvements that were needed considering the problems originally detected.

4.1.1. Primary guidelines

4.1.1.1. Action guide. A major improvement to the design of the CMPG was the development of a script, where the presentation times for texts and events that the students see on screen are coordinated with feedback mechanisms for each quest, which are defined both for individual and collective actions. The goal of this script is to improve the game's coherence, expressed in the students' motivation to participate in the activity.

Table 2
A list of design guidelines for classroom collaborative games.

Game mechanics: how should the game be played?
1. Interactivity and guidance
- The game must offer guidance, both for individual and collective action, through precise, timely and constant information regarding success and failure in performance.
- The user's interaction with the game must be simple and intuitive and not add unnecessary complexity to the game.

2. Mechanics linked to learning objectives
- The curricular content must be embedded in the game's functioning mechanics in such a way that the game's success is conditional to understanding its content.

Game progression: how should the game evolve?
3. Clear narrative
- The game must have a base story that allows the participants' immersion.
- The narrative should be composed of quests and challenges that define collaborative activities in a sequential and precise pattern.

4. Gradual increase in difficulty
- The videogame must have a script with a complexity structure associated to instructional strategies.
- The learning progression needs to be reflected by the instructional strategy and the difficulty progression in the game.

Methodology: how does the game help the instructional strategy?
5. The teacher is a mediator during the game
- The game's design must have a flexible structure that enables the teacher, who is the game moderator and guides the flow of actions, to adjust the game to the actual participation of the students in the classroom.

Collaboration: how can teamwork between the game's participants be improved?
6. Organize face to face interaction
- The game must use elements such as the underlying story and scene cuts to favor the teacher's mediation and promote communication between students.

7. Mechanics linked to collaboration
- Collaboration must be embedded in the game's functioning mechanics so that its success is conditional to having worked collaboratively.

On-screen information: how should the game look?
8. Adequate spatial distribution
- The system must distribute characters and activities around the map so as to take advantage of the available space.
- The system must relate camera control to the interaction of the characters on the screen, so as to favor players' interdependence and the exploration of the virtual world when appropriate.
- Spatial distribution should correctly relate aspects of the embedded knowledge to its connection with the real world.

9. Recognizable elements
- Characters and elements on the screen must have distinctive traits that capture the players' attention (color, shape, and action).

10. Accessible language
- The text on the screen must have a clear message, be concise and easy to read, facilitating the comprehension of the elements presented in the scene.
- Spoken text should be preferred over written text because it induces less cognitive load.

11. Avoid information overload
- Individual information must not stand in the way of collective information and must be relevant to the problem that needs to be solved.

Holism: how can a holistic experience that satisfies the ludic and instructional aspects of the game be created?
12. Action guide
- The game must have a systematic design that includes the educational and ludic aspects, through a script that specifies action sequences, possibilities for action, and events that might take place both in the virtual world and in the real world.

4.1.1.2. The teacher is a mediator during the game. Another important problem in the original implementation was the inability of the teacher to control the flow of the game. After the game started, the teacher lost the focus of the students in the game and it was really hard to get it back. To solve this problem, the possibility of stopping the game was introduced so the teacher could control the flow and support the students' work.

We explicitly designed two types of pauses: during the game (development pause, which can be one or many pauses), and at the end of the game (final pause). To improve student comprehension and participation in the activity, we specified guiding questions for development pauses with the goal of reinforcing specific game elements or concepts. Some of the guiding questions to stimulate the discussion between the teacher and students were: Why is there an alert message on the screen? What can each student do to solve this situation as a group? What are we asking from our classmates?

In the final pause, we aimed to favor the metacognition of the work carried out, expressing what was learned from the experience. The facilitating questions were: Why did we win/lose the game? What characterizes the elements? What explains the elements' behavior? What individual or collective actions explain the final result?

4.1.1.3. Mechanics linked to learning objectives. To improve learning, *explicit game rules* were designed which tell players what can and cannot be done to win the game. These rules are directly related to the learning objectives, forcing the students to advance in the game only when they understand the specific objective.

The rules were presented explicitly at the beginning, and throughout the game, showing on the screen individual and collective actions necessary in order to proceed. There were rules to hunt, plant, harvest, etc., as well as general instructions, such as "do not kill all herbivores". These explicit rules helped to reinforce both the goals in the game and the learning objectives of the class.

4.1.1.4. Gradual increase in difficulty. In the original game the complexity of the game didn't allow the students to complete all the quests, which directly impacted on the learning objectives. To solve this issue, a simpler food chain was developed that adjusts the conceptual complexity of the quests as follows: Quest 1: getting to know the virtual world through collective actions and interaction with the plants; Quest 2: interaction with herbivores; Quest 3: interaction with carnivores; Quest 4: interaction with carnivores through a collaborative strategy; Quest 5 and Quest 6: maintaining the balance of the entire food chain.

Through each quest, the difficulty of both the players actions and the educational content is gradually increased; in Quest 1 players must try their individual abilities; in Quest 2 each player keeps carrying out individual actions, but with a global goal of maintaining the balance between plants and herbivores; in Quests 3 and 4 players must coordinate their individual abilities to hunt carnivores; finally, in Quests 5 and 6 players must coordinate all the characters' abilities to maintain the balance between all the elements of the chain.

4.1.2. Secondary guidelines

4.1.2.1. Interactivity and guidance. Alert messages were added to signal when the success of the quest was being jeopardized. Congratulatory messages were given when a quest was completed, or when a collaborative task was achieved. When a new scenario was shown it was also signaled. Whenever relevant to the game, messages about abilities and how to use them appeared constantly in every quest.

The addition of an experience bar to show points for favorable individual actions was considered, however, this was not carried out, as the curricular time allotted to the game is brief. In this way we avoided excessive information, as well as feedback mechanisms that require a learning period exceeding the available time.

4.1.2.2. Clear narrative. A base story was presented from the beginning of the game, explaining how the characters were part of it. Videos depicting the story were used, with the goal of achieving immersion in the game. Quests and challenges were relevant to the task of balancing the food chain and were coherent with the base story.

4.1.2.3. Organize face to face interaction. Participants were distributed throughout the classroom in such a way that they were all visible to each other and everyone could see the screen (Fig. 1). This favored collaboration within the game.

In addition to the development and final pauses, which are also an opportunity for collaborative dialogues, other pauses were implemented before students began a quest (initial pause), which gave them 3 min to discuss and design collaborative strategies.

4.1.2.4. Mechanics linked to collaboration. Interdependence between players was boosted with *implicit rules*. These rules are discovered by comparing actions between participants. They were not necessary in order to win the game, but they improved the players' efficiency and maintained motivation to participate in a virtual world where there were things to discover. An example of an implicit guideline was the fact that the hunter could carry seeds faster than the Shaman, which could be used to optimize the game-play if players discovered this rule and coordinated their work.

4.1.2.5. Adequate spatial distribution. To improve the spatial distribution, from the beginning of each quest, characters and events were distributed throughout the entire screen. Additionally, a new camera control was implemented, performing zooms in/out as characters got closer/farther away on the screen, promoting virtual world exploration.

4.1.2.6. Recognizable elements. The difference between the characters (Shaman and Hunter) was accentuated, and participants could choose their character's hair color, promoting recognition and identification. Additionally, each character action was animated. Regarding the rest of the game elements, specific shapes and colors were used to improve recognition of the plants, animals and seeds.

4.1.2.7. Accessible language. The texts used in the game were redefined, changing for brief texts, with a maximum of 15 words each and containing only information relevant to the current activity. The exposure time of the text on screen was calibrated to be appropriate to the students' reading speed. When the instructions were presented, the game was paused and the teacher read the text on the screen to favor integration of visual and verbal information.

Table 3
Percentage of students who didn't experience each of the problems.

No	Problems	% Students who didn't experience the problem
1	Lack of feedback and guidance	0.50
2	Unclear relation between game actions and learning content	0.32
3	Unclear and weak narrative	0.72
4	Too many concepts presented simultaneously	0.43
5	The teacher role in the game was not clearly defined	0.58
6	Lack of face to face interaction	0.43
7	Lack of collaborative game mechanics	0.49
8	Poor use of screen space	0.83
9	Unrecognizable elements	0.87
10	Inaccessible language	0.89
11	Information overload	0.86
12	Lack of coordination between all the aspects of the game	0 92

4.1.2.8. Avoid information overload. Individual information (Life, Energy and Hunger) was reduced and reorganized, placed at the top and bottom of the screen, next to the character's face. Only the character's name was placed closed to him or her. Iconic figures were used to inform about individual actions, for example, feeding.

4.2. Experimental study

A field study was performed in order to observe whether or not the modifications made according to the design guidelines helped to solve the initial problems. Participants in this research were twenty 11 to 13 year-old students from the 6th grade (where the food chain is studied) of an elementary school in Santiago, Chile. The school had similar socioeconomic characteristics to the school where the exploratory study was performed. The study was performed in two sessions, each one with 10 students because of the limitations of simultaneous players in the game (Fig. 1). One of the researchers acted as teacher during both sessions.

To measure whether or not the design guidelines helped to solve the initial problems, we developed a scale of dichotomic observations in order to mark "presence/no presence" of behaviors in participants that relate to the initial problems observed (Appendix A). For each problem, one or more observations were considered as indicators of it being solved. The observations were made for every quest of the game session, marking for each student whether or not the specific behavior described by the observation was present. The percentage of students that showed the behavior of all the observations related to each problem was used as a metric to show how well each guideline helped addressing its related problem.

To analyze the observations, the sessions were filmed with three cameras that recorded the participants' behavior in the classroom and on screen. Observation points were validated by agreement between three observers. For this study, we only took into consideration observations where the concordance index was greater than 0.75 calculated through the accordance ratio of the observers; all other observations were eliminated from the study. The final scale had 24 (out of a total of 32) observations, with a global concordance of 0.92.

In addition to these observations, we performed pre- and post-tests in order to validate that the students learned using the game. To assess the students' learning, we designed an instrument called Evaluation Test on *Notions of Food Chain Balance* (NFCB), composed of 20 items with multiple-choice answers; designed according to the curricular program (Ministerio de Educación, 2004). This test was examined and approved by three teachers who are experts in this area of the school curriculum. The analysis of the instrument's reliability and difficulty was done through the application of a test to 20 students of a similar age and educational level as those that comprised the study group. Cronbach's Alpha reliability was 0.74. The difficulty of the test was analyzed with a scale that produced scores that ranged from 0.05 (*very difficult)* to 0.99 *(very easy)*. The result was 0.46, calculated as the proportion of people who correctly answered the test items, which indicates that the test is of intermediate difficulty.

4.3. Results and discussions

Using the results of the dichotomic observations (Appendix A) for every student, we calculated the percentage of students who didn't experience each problem (Table 3). The results show that more than 80% of the participants didn't have problems with on-screen information (problems 8 to 11), and they didn't experience a lack of coordination between all the aspects of the game (problem 12). However, other problems didn't show this level of improvement. For example, only 32% of the students showed signs of a clear relation between game actions and learning contents (problem 2).

Table 4
Percentage of students without problems 1 to 7 on the specific quests.

N°	Problems	Quest 1	Quest 2	Quest 3	Quest 4	Quest 5	Quest 6
1	Lack of feedback and guidance	0.20	0.78	0.53	0.40	0.43	0.65
2	Unclear relation between game actions and learning content	NA[a]	NA[a]	0.16	0.49	0.59	0.70
3	Unclear and weak narrative	0.71	0.70	0.59	0.81	0.82	0.80
4	Too many concepts presented simultaneously	NA[a]	NA[a]	0.15	0.70	0.80	0.93
5	The teacher role in the game was not clearly defined	0.38	0.75	0.48	0.75	0.75	0.38
6	Lack of face to face interaction	0.35	0.49	0.40	0.56	0.60	0.55
7	Lack of collaborative game mechanics	0.35	0.44	0.36	0.65	0.68	0.69

[a] NA = Not applicable.

Table 5
Comparison of pre- and post-test by gender.

		Mean	Standard deviation	T	Significance (bilateral)	Cohen's d
Boys	Pre-Test	9.62	2.71	3.13	0.005	0.5 Medium
	Post-Test	11.10	3.34			
Girls	Pre-Test	9.05	2.34	2.08	0.051	0.55 Medium
	Post-Test	10.32	2.38			

A more detailed analysis was performed for problems 1 to 7, measuring for each quest of the game the percentage of the students who didn't have each problem. The 6 quests of the game were:

1. Move as a group, plant greenery.
2. Hunt herbivore, feed character.
3. Move as a group, hunt carnivore without previous strategy. 4. Design strategy to hunt carnivore using strategy.
5. Keep balance, first attempt.
6. Keep balance, second attempt.

As Table 4 illustrates, when closely observing these results, we can see that for problems 1 to 7 the percentage of students with the problem changes drastically from quest to quest. For example, for Quest 2, more than 70% of the students didn't show signs of lack of feedback and guidance (problem N°1), unclear narrative (problem N°3) and unclear role of the teacher (problem N° 5), but in Quest 3, where the solution requires a group strategy, these percentages fall. We can also see that, in general, the presence of problems decreases as of Quest 4. This is especially true for problem N°2 (unclear relation between game actions and learning content) and N°7 (lack of collaborative game mechanics), where students must work collaboratively in order to achieve goals. The increase of problem N° 5 (the teacher role in the game was not clearly defined) in Quest 6 is linked to an increase in the participants' autonomy for teamwork and greater mastery of the game. Finally, problem N°4 (too many concepts presented simultaneously) and N°2 (unclear relation between game actions and learning content), were not relevant in the initial sequences of the game (Quests 1 and 2) because participants interact with the screen and the teacher individually, in order to understand the elements of the game and their characters' attributes. But as of Quest 4, where a collaborative use of attributes is required, the number of students with these problems decreases progressively.

The degree to which a specific problem was solved can be interpreted as a measure of how helpful the design improvements, related to the specific guidelines, were. The four primary guidelines considered for the game redesign were linked to problems 2, 4, 5 and 12. Of these guidelines, only the *Action guide* guideline can be seen to have successfully helped in solving the original problems. The fact that, even in the final quest, 30% of students showed unclear relation between game actions and learning content, suggest that the redesigns performed following the *Mechanics linked to content* guideline were not enough. In some quests, the clarity and impact of the role of teacher was low, and too many concepts were presented simultaneously, suggesting that the design changes related to both *The teacher is a mediator* and *Gradual increase in difficulty* guidelines were not effective for every quest.

Most secondary guidelines achieved a good result in solving the original problem. The main reason for this is that, although the redesign aspects of these guidelines were not prioritized as high as the one of the primary guidelines, most of the changes needed to improve the CMPG were small and easy to implement, and the problems themselves were simple. The problems related to the primary guidelines, however, were more complex, involving the interplay of many elements during the session.

The results of the pre/post-test experiment showed that scores obtained on the NFCB test are higher in the post-test, with statistically significant differences ($p < 0.001$) and medium effect (Cohen's $d = 0{,}51$). The gender analysis showed that this result is present both in boys and girls, as can be seen in Table 5.

5. Conclusions

The main contribution of this work is the definition of a set of guidelines that help the design of CMPGs. These guidelines were proven to be useful in general when redesigning a game to solve its original problems, which was shown both by the results of the observations made of the activity and also by the learning results measured with the pre-post experimental design. The goal of any educational game is to improve the learning of the students, and the results obtained in this work suggest that the use of the design guidelines helped to achieve this goal. While primary guidelines, defined by their importance in defining the learning and game experience, convey different elements making the corresponding problems hard to solve, most secondary guidelines solved the diagnosed problems.

There are additional valuable lessons which were obtained from this experience. Although the design guidelines can be seen as general principles necessary to be considered in this kind of game, the detailed analysis made for each quest shows that in some circumstances some guidelines could be left aside, and in other moments they may even be contradictory. For example, the initial quests, which are focused on teaching the game, could limit some collaborative mechanics in order to ease the learning process. Also, in the final quests, where the students are mastering the game, the teacher may take a more secondary role and decrease his/her interventions in order to maximize the engagement of the class with the game. This suggests that the importance of some guidelines varies throughout the game, and this must be considered in order to make more informed design decisions.

The set of guidelines presented here are clearly not complete, but they present a step in defining principles that can guide the design process of CMPGs. Some of the guidelines can be considered as basic interface design principles (i.e., on-screen information guidelines), but we still considered it relevant to include them here, and restate their importance for this type of game. As future work, we would like to explore in more detail how these guidelines (and possibly additional ones) can be best used in different moments of the game, which would help to decide when a specific guideline must be applied and when it may be optional.

The implementation of videogames in the classroom has a level of effectiveness and results that depend on design (Amory, 2007). We must take into account that the game's mechanics are the first barrier in learning the contents provided by the CMPG. This is why, in a preliminary study, we considered that the use of a videogame in the classroom requires one session to master the game and another to use it in the learning process (Susaeta et al., 2010). However, this study demonstrated that, if the CMPG's design doesn't carry the information load that is typical in online games, and maintains its ludic properties, it allows players to learn its mechanics and components in a few minutes, allowing the game to be used as an educational tool in one session.

The design guidelines presented here can be complemented with additional methods and guidelines for the curricular integration of contents and quests. For example, Bloom's revised taxonomy (Anderson et al., 2001) has been used as a design guide for defining the learning objectives and, based on those objectives, specifying the quests (Echeverría et al., 2011). The combination of these guidelines is something we plan to study further, in order to understand how they can be used together to create better educational games for the classroom.

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Appendix A

Dichotomic observations used to measure how well the different problems of the original games were resolved in the redesigned version. In the table under Observation we indicate the expected outcome and under Associated Problems the original problems detected.

	Observation	Associated problems
1	More than half of the characters are not grouped in one specific sector of the screen, while game events are happening in a different sector.	Poor use of screen space
2	Characters are participating in all of the game events, located in different parts of the map.	Poor use of screen space
3	The player recognizes his/her character on the screen.	Unrecognizable elements
4	The player identifies his/her role as Shaman or Hunter in the game.	Unrecognizable elements, Information overload.
5	The player actions are coherent with the current elements on screen.	Unrecognizable elements, Information overload.
6	The player actions are coherent with the current actions being made by elements on the screen.	Unrecognizable elements, Information overload.
7	The player keeps his/her focus on the screen when there text instructions are displayed.	Inaccessible language, Information overload.
8	The player actions are coherent with the instructions on screen.	Inaccessible language, Information overload.
9	The player performs the correct actions when feedback information changes (level of hunger, energy, life).	Lack of feedback and guidance
10	The player talks with other players about the story and game elements.	Unclear and weak narrative, Lack of collaborative game mechanics
11	The interaction between the player and the rest of the characters is the most efficient in order to solve the quest (he or she takes part in two or three player activities with success)	Too many concepts presented simultaneously, Unclear relation between game actions and learning content, Lack of collaborative game mechanics
12	The player states his/her opinion during pauses or gameplay.	Unclear and weak narrative, Lack of face to face interaction, Unclear relation between game actions and learning content
13	The player suggests concrete actions to other players during pauses or gameplay.	Lack of face to face interaction, Lack of collaborative game mechanics
14	The player asks questions or gives support to other players during pauses or gameplay.	Lack of face to face interaction, Lack of collaborative game mechanics
15	The player is not disruptive during pauses or gameplay.	Lack of face to face interaction, Lack of collaborative game mechanics
16	The actions performed by the player relate to solving the quest are caused by a comment made by another player.	Lack of collaborative game mechanics
17	The actions performed by the player relate to solving the quest are caused by the player's own initiative.	Lack of collaborative game mechanics
18	The player performs actions related to solving the quest.	Lack of collaborative game mechanics
19	There was agreement between the players and the teacher as to the best strategy to use in solving the quest.	The teacher's role in the game was not clearly defined, Lack of face to face interaction, Lack of collaborative game mechanics
20	The player shows satisfaction about his role in the game (positive emotional expressions).	Unclear and weak narrative, Lack of coordination between all the aspects of the game
21	The player doesn't show insatisfaction about his role in the game (positive emotional expressions).	Unclear and weak narrative, Lack of coordination between all the aspects of the game
22	The player does not appear indifferent to the current events in the game.	Unclear and weak narrative, Lack of coordination between all the aspects of the game
23	The player shows that he learned the content during the game, making comments that suggest that he knows what to do and why he won or lost.	Unclear relation between game actions and learning content
24	The player does not appear confused.	Lack of coordination between all the aspects of the game:

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