The LM-GM framework for Serious Games Analysis

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Abstract

This document proposes the Learning Mechanics-Game Mechanics (LM-GM) model, which supports SG analysis and design by allowing reflection on the various pedagogical and game elements in a SG. The LM-GM model includes a set of pre-defined game mechanics and pedagogical elements that we have abstracted from literature on game studies and learning theories. Designers and analysts can exploit these mechanics to draw the LM-GM map for a game, so as to identify and highlight its main pedagogical and entertainment features, and their interrelations. The tool may be useful also for teachers to evaluate effectiveness of a given game and better understand how to use it in educational settings.

Introduction

The principles of learning and game-play are different and frequently conflicting, but they can coexist in well designed SGs. This suggests that high-level pedagogical intents can be translated and implemented through low-level game mechanics. Based on this assumption, our paper introduces the concept of *Serious Game Mechanic* (SGM) defined as *the design decision that concretely realises the transition of a learning practice/goal into a mechanical element of game-play for the sole purpose of play and fun*. SGMs act as the game elements/aspects linking pedagogical practices (represented through *learning mechanics*) to concrete game mechanics directly related to a player's actions. In this paper, the mechanics of learning refer to *the dynamic operation of learning, that we typically model relying on learning theories and pedagogical principles.* This encompasses components (such specific objectives, tasks, activities, methods) that make up a learning strategy, instructions or process influenced by the context of learning.

As part of the development and validation of the SGM models, this paper reports on the ongoing findings of game analysis using the Learning-Mechanics and Game-Mechanics (LM-GM) model, a framework that allows SG mapping that highlights the main learning and game mechanics involved in each game situation, thus supporting the identification and analysis of emerging SGMs. As such, the tool is intended both for designers and for teachers to evaluate effectiveness of a given game and better understand how to use it in educational settings.

Learning Mechanics-Game Mechanics (LM-GM) model

In this paper, we aim to address the identification of the key components (we call them SGMs, see figure 1) that can be replicated, with the proper differentiations, across different SGs. The goal is to favour an efficient analysis of SGs and support specification of new designs.

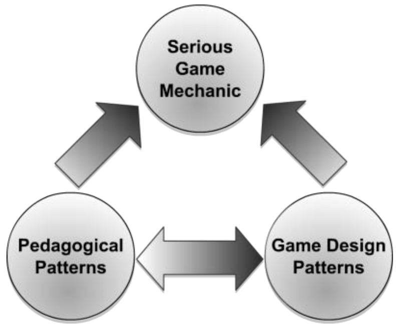

Figure 1. The relationship between Serious Games Mechanics (SGMs) and the pedagogical and game design patterns of a game.

Learning is a very complex human activity, which has been investigated and modelled through several pedagogical theories and approaches, such as behaviourism, cognitivism, humanism, personalism, constructivism, etc. The LM-GM model has been designed to allow different users describe games on the basis of different pedagogical approaches. In particular, LM-GM's learning mechanics include various aspects (e.g., tasks, activities, goals, relationships) that we have derived from different pedagogical approaches and that an LM-GM user can map to different game mechanics, according to the specific nature of the SGs under analysis.

Formulating LM-GM

In SGs, game play should support intrinsic experiential learning. It is therefore reasonable to postulate that knowledge acquisition and skill training should be obtained through game mechanics (e.g., quests, cascading information, leader boards, goals, levels, badges, role-play, tokens, etc.) – and not, for instance, from related user manuals. Thus, we tried to investigate how to establish relationships between the mechanics present in educational philosophies (pedagogical theories and strategies) and those of games.

We formulated this as the learning-game mechanic (LM-GM) model. Figure 2 depicts the components of the model, namely the learning mechanics (LMs, represented as nodes in the left side of the picture) and the game mechanics (GMs, represented as nodes in the right side of the picture). The overall framework also includes a detailed description of the meaning of each featured mechanics. The model is descriptive and not prescriptive, in the sense that it allows its users to freely relate learning and gaming mechanics to describe SG situations by drawing a map and filling a table. On the one hand, the table expresses the "static" relationships, inside the SG, between learning and game mechanics, also detailing the actual implementation (as game mechanics are abstract and generic) and usage by the player. An example is provided in table 3. On the other hand, the map offers a dynamic view of the relationships as it allows drawing the LMs and GMs in the various phases of an SG flow of actions. An example of the resulting map for a SG is provided in figure 3. Overall, the LM-GM model aims at providing a concise means to relate pedagogy intentions and ludic elements within a player's actions and game play, i.e. SGMs.

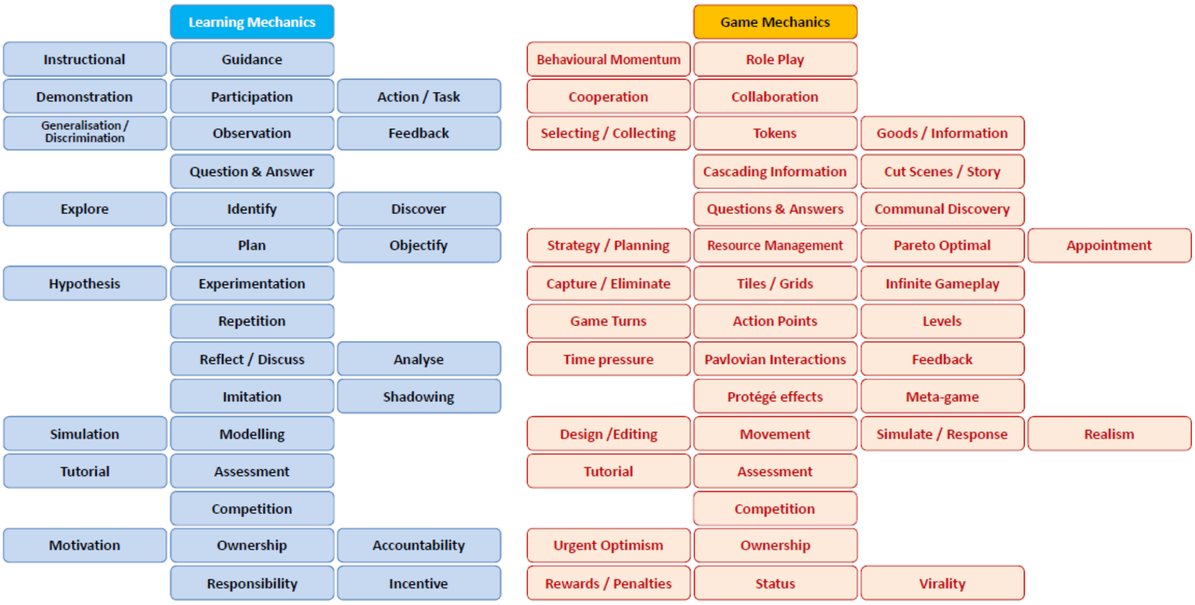

Figure 2. Learning and game mechanics used as the basis to construct the LM-GM map for a game

The LM nodes illustrated in figure 2 are a non-exhaustive list of learning mechanics that have been extracted from literature and discussions with educational theorists on 21st century pedagogy, considering a variety of educational theories (e.g., constructivism, behaviourism, personalism), in particular those closer to game education (Keller, 1983; Gagnè, 1992; Papert and Harel, 1991; Brainerd, 1978). In the same manner, the GM nodes were obtained by reviewing articles on game mechanics and dynamics, and they represent the backbone of many game theories (Järvinen, 2008; Sicart, 2008; Bellotti et al, 2009a; Bellotti et al, 2009b; Connolly et al., 2012). Proper combinations of these mechanics may be applied in several SG application domains, from languages to science, humanities and arts.

Application

For simplicity, the reading of the LM-GM model can be viewed as having two axes. On the horizontal axis lie the learning and game mechanics analogous to a breadth-first search. Core components run vertically down from the two root nodes (of learning mechanics and game mechanics respectively) in a manner similar to a depth-first search. Side or leaf nodes represent functional mechanics supporting the core.

From a pedagogical perspective, one would argue that how a user learns is, in essence, more important than the domain specificity of the medium through which the learning is performed. Based on Bloom's theory (Bloom, 1956), a simplified framework/ classification (Table 2) organised in line with the digital taxonomy of Anderson and Krathwohl (2001) can be used to link commonly found game mechanics to learning mechanism. As an example, this table emphasises upon task-centred learning rather than cognitive learning. Indeed, a game can be seen as a continuous assessment of gained knowledge as the player proceeds from level to level.

So, a user of the model should identify which LM and GM are (or should be, in case of design) used in each game situation (among the ones listed in Figure 2), describe their relationships and implementation (e.g., Table 3) and show on a map their dynamic appearance during the game flow of actions (e.g., Figure 3).

GAME MECHANICS	THINKING SKILLS	LEARNING MECHANICS	
○ Design/Editing ○ Infinite Game play ○ Ownership ○ Protégé Effect ○ Status ○ Strategy/Planning ○ Tiles/Grids	CREATING	○ Accountability ○ Ownership ○ Planning ○ Responsibility	LOTS to HOTS
○ Action Points ○ Assessment ○ Collaboration ○ Communal Discovery ○ Resource Management ○ Game Turns ○ Pareto Optimal ○ Rewards/Penalties ○ Urgent Optimism	EVALUATING	○ Assessment ○ Collaboration ○ Hypothesis ○ Incentive ○ Motivation ○ Reflect/Discuss	
○ Feedback ○ Meta-game ○ Realism	ANALYSING	○ Analyse ○ Experimentation ○ Feedback ○ Identify ○ Observation ○ Shadowing	
○ Capture/Elimination ○ Competition ○ Cooperation ○ Movement ○ Progression ○ Selecting/Collecting ○ Simulate/Response ○ Time Pressure	APPLYING	○ Action/Task ○ Competition ○ Cooperation ○ Demonstration ○ Imitation ○ Simulation	
○ Appointment ○ Cascading Information ○ Questions And Answers ○ Role-play ○ Tutorial	UNDERSTANDING	○ Objectify ○ Participation ○ Question And Answers ○ Tutorial	
○ Cut scenes/Story ○ Tokens ○ Virality ○ Behavioural Momentum ○ Pavlovian Interactions ○ Goods/Information	RETENTION	○ Discover ○ Explore ○ Generalisation ○ Guidance ○ Instruction ○ Repetition	

Table 2. Classifications based on Bloom's ORDERED Thinking Skills

By exploring the LM-GM model, the GALA network aims to address the mismatch between game mechanics and educational components at the design and development level. The model enables further questioning as to whether the games should adapt to existing pedagogical practices or whether they should be used to change practices since they form an entity which functions to educate and entertain through a single compelling experience. The impact from the SGMs investigations would draw out larger research themes on the intersections of games and pedagogy (both traditional and new). It will also pave the way for a toolset rather than a black box for designing content specific SG. It is important to note, though, that the LM-GM framework is not a formulaic means to design SGs. The purpose of the LM-GM is to support working with SGMs by functioning as a regression tool for developers and as analytic tool for those interested in studying the mechanisms joining pedagogical and game features.

Case study: LM-GM as an analysis tool

In this section, we describe a case study aimed at showing how to apply the framework in the analysis of the relationships between pedagogy and game mechanics in a state of the art SG such as *Re-Mission* (Kato et al., 2008).

Re-Mission is a game of the third-person-shooter (TPS) genre set within the bodies of young patients diagnosed with cancer, in which the player is tasked with aiding a virtual patient combat the disease and its effects. This game was chosen given its popularity and acknowledged effectiveness in the field, and because of the need to understand better whether its game mechanics at their implementation level are inherently pedagogically beneficial. Reported works (Kato et al, 2008; Tate et al, 2009, Wouters et al, 2011; Cole et al, 2012; Mader et al, 2012) on *Re-Mission* often do not sufficiently specify measures related to productive learning as a result of the game mechanics. Indeed, in several SGs, extraneous (i.e. pedagogy-independent) game mechanics are often designed to enhance game play. Consequently, learning occurs only tangentially, and mainly due to the contents. However, providing contents non-related with game mechanics (e.g., by inserting long texts, almost independent from the actual game play) leads to games that are boring or not able to achieve their educational target. In this context, we are using the LM-GM framework as a means to determine at which point game-play and pedagogy intertwine, which is a key concern for SG design.

The first step of the model application consists of the identification and description of the actual game and learning mechanics. The resulting analysis, reported in Table 3, suggests that the game-play follows a constructivist nature of learning, experienced by the player in a roughly sequential order from top to bottom.

Game mechanic	Learning mechanic	Implementation	Usage
Cut scene / Story	Instructional	Pre-rendered videos	To explain gameplay mechanisms via storytelling.
Cascading information Tutorials	Guidance Tutorial	NPC Levels	Guide user through basic mechanics to complete an activity.
Selecting / Collecting	Activity / Project Action / Tasks Discovery Problem-based solving	Power-ups Ammo	Rewards / Sense of empowerment
Movement		3D environment interaction for control, fly-through / navigate	Immersion, interacting with content, e.g. delivery of medication.
Capture / Elimination		Destroy cancer cells	Prevent cancer cell multiplication
Time pressure		To enhance activity, engagement	To highlight urgency
Protégé effect	Motivation External thinking Responsibility	Virtual patient response and conditioning; governed by state if medication.	To relate player to game character, i.e. the patient, such that medication is not missed.
Feedback	Feedback	Level upgrading Prompts / Cut scenes Player status	End of levels. Motivation. Message reinforcement.
Behavioural momentum	Repetition Reflection	Levels	To trail multiple contingencies in order to cover a wide range of potential treatment and pitfalls.

Table 3. The analysis based on Re-Mission

To establish the pedagogical intent of the game mechanics it is necessary to understand that the content of *Re-Mission* was designed to achieve game-based behavioural change, thus it addresses behavioural issues. The game play was designed through a rational engineering approach, which produced the definition of six core principles that were implemented in the game (Tate et al, 2009):

P1. Choose a target health outcome: This defines the learning outcome for each game level;
P2. Identify its key behavioural mediators: This defines the risk associations with poor adherence of medication;
P3. Define the psychological determinants of behaviour: This defines the behaviour that must change to address P2;
P4. Capture that perceptual field in the game-play: This was designed to remind that all may not be as well as thought, i.e. that cancer could still be prevailing;
P5. Live out contingencies in the virtual world instead of real life: This was designed such that the player can observe the consequences of poor medication behaviour;
P6. Always have fun (Behaviour = Knowledge x Motivation): The aim was purely to express that through fun the game can effectively generate overt behaviour change.

The execution of principles P3-P6, that specifically target achievement of learning outcomes, are of particular interest in our analysis. From the observation, it is possible to note that the game was designed to cycle through these principles for each individual health outcome, with each level targeting a different outcome. Gamers who are familiar with the third person shooter genre may quickly recognise this game-play "loop" and recognise its relevant game mechanics (Figure 3).

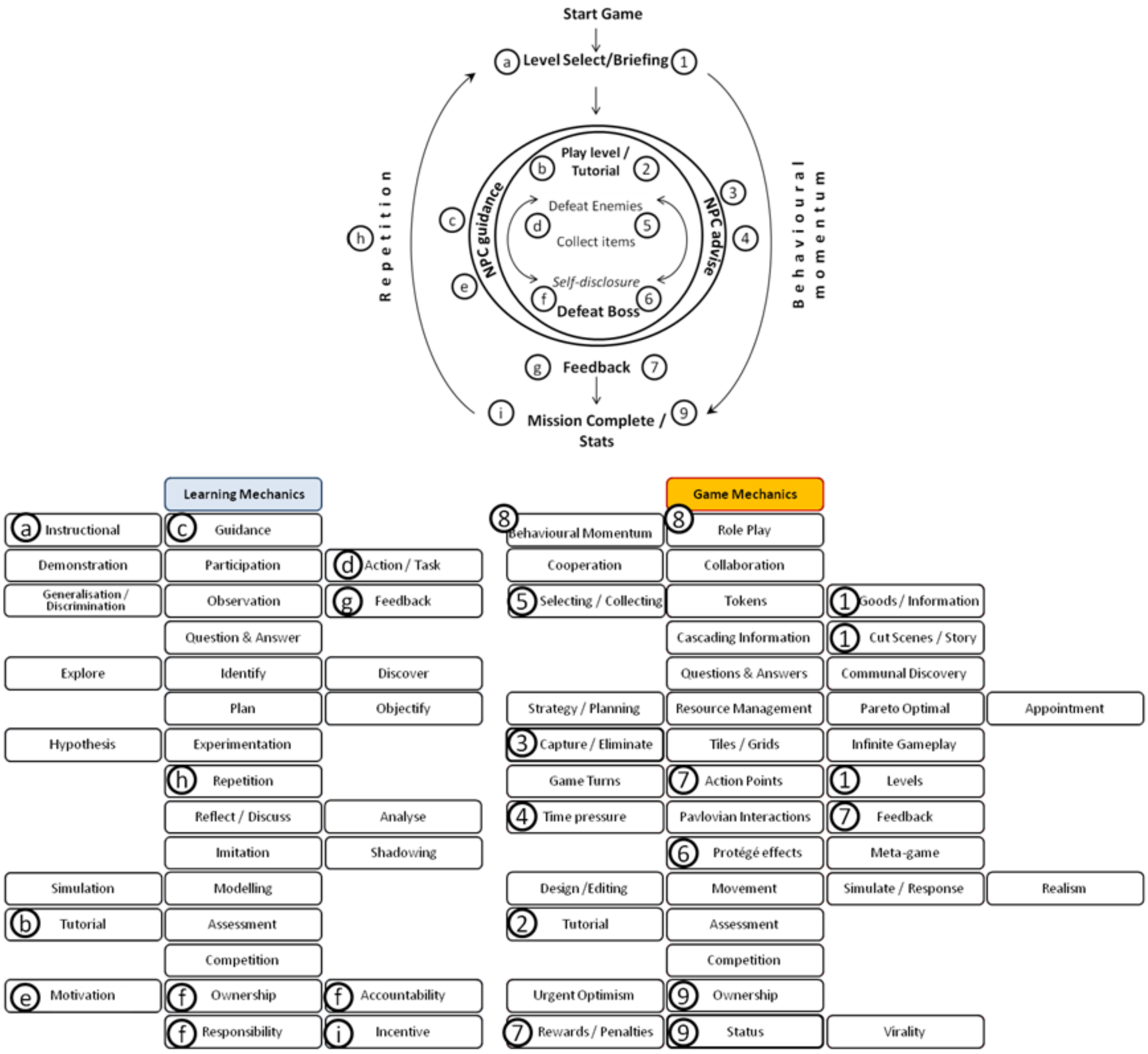

Figure 3. A game map constructed through an LM-GM-based analysis of Re-Mission

P5, which relates to the negative consequences of poor treatment adherence, is of particular interest. The LM-GM framework identifies this as creating a protégé effect in the user, in which they learn the motivation for their own correct behaviour by teaching another person or entity the correct set of actions. This seems to be a core concept of the learning principle behind *Re-Mission.*

What is the logical relationship between GMs and SGMs? In *Re-Mission*, the mechanics associated with player actions fall under the protégé effect, in which the action of teaching others is used as a learning tool. This is similar to a forward model in distal supervised learning, as evidenced by each *Re-Mission* assignment, where the player is informed of a case history and the mission prior to launching into the game. Additionally, during the mission preview, the non-player character (NPC) adviser discusses strategies for battling a specific ailment. The mechanics are now beginning to blend into pedagogy. In having a protégé effect one considers the game mechanic as engaged in the action of "teaching". The protégé effect is not a learning goal, but is the SGM through which the goal can be achieved. In *Re-Mission* the goal was identified with imparting health related suggestions and motivations to the player, teaching patients to take responsibility for their own health.

This case study has shown how LM-GM can help identify both high level learning goals and lower levels LMs, SGMs and GMs. In the following section, we are interested in validating the model through user tests.

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