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Mapping Learning and Game Mechanics for Serious Games Analysis

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ABSTRACT

While there is a consensus on the instructional potential of Serious Games (SGs), there is still a lack of methodologies and tools not only for design but also to support analysis and assessment. Filling this gap is one of the main aims of the Games and Learning Alliance (GALA, *www.galanoe.eu*) European Network of Excellence on Serious Games (SGs), which has a focus upon *pedagogy-driven SGs*. This paper relies on the assumption that the fundamental aspect of SG design consists in the translation of learning goals/practices into mechanical element of game-play, serving to an instructional purpose beside that of play and fun. This paper 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 also be useful for teachers to evaluate the effectiveness of a given game and better understand how to implement it in educational settings. A case study is reported to illustrate the framework's support in determining how game-play and pedagogy intertwine in a SG. Finally, the paper presents the results of two comparative user tests demonstrating the advantages of the proposed model with respect to a similar state-of-the-art framework.

1. INTRODUCTION

Serious Games (SGs) are gaining ever more interest as an instructional tool capitalising on the appeal of games and the effectiveness of Information and Communication Technologies (ICTs). Recent ICT advances have led to the implementation of realistic virtual environments and simulations, where players can live compelling adventures while acquiring, practicing and verifying knowledge, according to various pedagogical paradigms (Bellotti, Berta, Gloria, & Primavera, 2009a). This represents a significant opportunity for 21st century educators and trainers to enhance their educational toolkit.

However, a major challenge lies in translating interest and potential into actual adoption and use. SGs must demonstrate the transfer of learning (to be 'serious'), whilst also remaining engaging and entertaining (to be 'games'). The balance between fun and educational measures should be targeted throughout the development starting from the design phase. Yet, despite the digital games' potential

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in terms of interactivity, immersion and engagement, more work is still required to understand how to better design, administrate and evaluate digital games across different learning contexts and targets (Alvarez & Michaud, 2008; Dror, 2008; Westera, Nadolski, Hummel, & Wopereis, 2008; Ulicsak, 2010; Bellotti, Berta, & De Gloria, 2010b; de Freitas & Liarokapis, 2011). One of the biggest issues with educational games to date is the inadequate integration of educational and game design principles (e.g. Kiili & Lainema, 2008; Gunter, Kenny, & Vick, 2006; Kenny & Gunter, 2007; Lim et al., 2013). This is due to various factors including the fundamental fact that digital game designers and educational experts do not usually share a common vocabulary and view of the domain (Gunter et al., 2006). This perspective is also shared by Kiili and Lainema (2008), and Lim et al. (2013). There is hence a need to improve the theoretical basis behind the design of SGs, considering the underlying pedagogic principles and the contexts of use, which are also key to the success (Bellotti, Berta, & De Gloria, 2012).

The principles of learning and game-play are different and frequently conflicting, but they can coexist in well designed SGs (Huynh-Kim-Bang, Labat, & Wisdom, 2011). 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 for both designers and teachers to evaluate the effectiveness of a given game and better understand how it can be used within an educational setting.

The remainder of the paper is organised as follows. The next section discusses existing work/models such as the game-based learning framework and the Amory's (2007) Game Object Model (GOM). The discussion continues with a section on the conceptual background and the methodology behind the LM-GM model. In order to provide evidence on the potential use of the model as an analytic tool, the following section describes a case study that illustrates the use of LM-GM as a tool to analyse how game-play and pedagogy intertwine in a game. For further validation, the paper describes the results of a comparative study between the LM-GM model and the GOM. Finally, the conclusion section summarises the results and sketches directions for future research.

2. RELATED WORK

It can be readily seen from entertainment gaming that certain genres, such as role-playing, action, adventure and simulation, share similar interaction models and game-play dynamics among several different titles. Game mechanics (GMs) are well understood and established in the context of entertainment games. Sicart (2008) cited a plethora of game mechanics definitions but concluded these were neither precise nor inclusive. Sicart subsequently formalised a systemic structure that provided an ontological distinction between rules and mechanics. The Game Ontology Project (GOP) provides a wiki-enabled hierarchy of elements of gameplay used by games studies researchers (Zagal & Bruckman, 2008).

Building on top of the topology of game-play rules defined by Frasca (2003), Djaouti, Alvarez, Jessel, Methel, and Molinier (2008) propose videogames classification based on the concept of 'Game play Bricks', where the different combinations of the "fundamental elements" seem to match the different rules and goals of videogames. They also identified two different types of game rules:

the rules that allow the player to "manipulate" the elements of the game, and, at a higher level, the rules defining the "goal" of the game. Generally, GMs express players' agency in the game world via actions (Järvinen, 2008; Sicart, 2008) and consequently are expressed at a lower level through several manipulation rules. These rules focus on 'inter/action' type game mechanics that have little pedagogical value. We thus argue that learning must therefore be defined at a higher level, through goals, rules and other components that have a pedagogical value.

Similarly to games purely for entertainment, SGs also have generic components that are replicated and adapted through different titles. However, SG-specific mechanics have yet to be conclusively identified and described. We argue that this is because of the greater complexity and the less diffusion of SGs with respect to games. SGs are quite varied in terms of features and can potentially offer different kinds of learning experience. It is thus important to understand how different game elements can contribute to an effective facilitation of learning. Ritterfeld, Cody, and Vorderer (2009) elaborate on the underlying theories that explain suggested psychological mechanisms elicited through serious game play, addressing cognitive, affective and social processes. Bellotti, Berta, De Gloria, and Zappi (2008) explored the embedding of simple 2D microGames (mGs) inside a 3D environment, challenging players to extract in-depth knowledge about some particular items embedded in a reconstructed 3D context. This is part of the sandbox SG design model, which has proved to be particularly effective in the cultural heritage domain (Bellotti, Berta, De Gloria, D'Ursi, & Fiore, 2013).

Kenny and Gunter (2007) explored complex learning goals and argue that learning content within a game could be highly related to (i.e. highly immersed in) the game's narrative elements. Existing game-based learning frameworks, such as the Four-Dimensional Framework (4DF) (de Freitas & Oliver, 2006) and the game-based learning framework (van Staalduinen & de Freitas, 2010) attempted to address similar issues by prescribing games to be designed based on the considerations relevant to the traditional learning context. An interest for exploratory learning, problem-based learning and inquiry learning has been noted in the theory-based pedagogy literature (see extracts from learning theories collected in de Freitas and Jameson (2012)). The RETAIN model assesses how well educational games contain and incorporate academic content and promotes transfer of knowledge (Gunter, Kenny, & Vick, 2008). The model correlates to three learning theories that are most closely aligned with generally accepted game design principles, namely: Keller's ARCS Model, Gagne's Events of Instruction and Piaget's ideas on schema. Westera et al. (2008) argue that existing frameworks have been effectively used as evaluation guidelines, where game design can be analysed with respect to the educational context. Synthesizing, while the existing practices, frameworks and models in serious games design appear to take serious game mechanics into consideration, they do not specifically target the analysis of the relationships between game mechanics and learning constructs, which is a key factor in game design for learning. There is a need for a framework that is more comprehensive and explicit in terms of how learning components and game components are related to one another. The principles of learning and game play, in fact, can be conflicting and making them effectively co-exist is a typical and major challenge of SG design (Huynh-Kim-Bang et al., 2011).

Amory (2007) presented the Game Object Model (GOM), a constructivist theoretical framework to support educational games development based around the notion of interrelated components, or, in other words, units that have dependencies and relationships with one another. The model comprises five distinct state spaces: Game Space, Visualisation Space, Elements Space, Actor Space and Problem Space. Analogously to object-oriented programming, Amory considers educational games to contain components (objects) that can be described though abstract interfaces (pedagogical/theoretical components) and concrete interfaces (game design components), as shown in Table I.

Table I. The theoretical constructs of each object in GOM indicating the Abstract (a) and Concrete (c) interfaces.

Game space	Visualisation space	Elements space	Actor space	Problem space
Play (a)	Critical thinking (a)	Fun (a)	Drama (a)	Puzzlement (a)
Exploration (a)	Discovery (a)	Emotive (a)	Role models (c)	Accommodation (a)
Challenges (a)	Goal formation (a)	Graphics (c)	Interact (c)	Assimilation (a)
Engagement (a)	Goal completion (a)	Sounds (c)	Gestures (c)	Complex (a)
Narrative (a)	Competition (a)	Technology (c)		Flow (a)
Authentic (a)	Practice (a)	Backstory (c)		Activity-based (a)
Multiple views (a)	Storyline (c)			Conflict (c)
Gender-inclusive (a)	Plot (c)			Explicit knowledge (c)
Transformation (a)	Reflection (c)			Conversation (c)
Tacit knowledge (a)	Relevance (c)			Model-building (c)
	Game rhythm (c)			Communication (c)
				Literacy (c)
				Memory (c)
				Motor (c)

Although generic and game-genre independent, GOM does not indicate how each unit influences one another nor how situational and contextual factors influence the game's design and the game play structure. Its high level operatives mean that GOM does not sufficiently support a description of a SG's learning aspects/goals and their relationships with game components.

We argue that what is really missing from the state of the art is a framework/model for discovering and understanding what game mechanics relate to relevant pedagogical objectives in a SG, which would support more efficient and effective analysis and design of SGs.

3. 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.

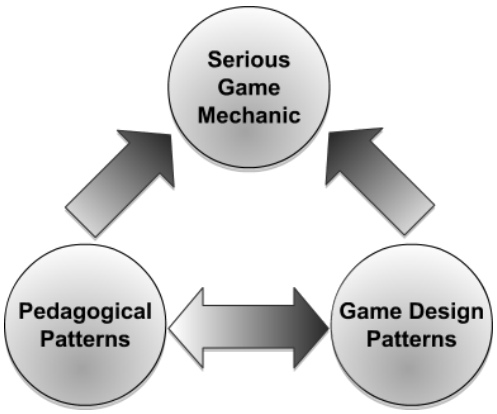

Figure 1. The relationship between Serious Games Mechanics (SGMs) and the pedagogical and game design patterns of a game

SGMs reflect the complex relationships between pedagogy, learning and entertainment/fun, joining educational and gaming agendas. Therefore, SGMs are the game components that translate a pedagogical practice/pattern into concrete game mechanics directly perceivable by a player's actions. While game design patterns (e.g. Huynh-Kim-Bang et al., 2011) provide design solutions to common SG issues/requirements, SGMs are finer grain components that can be exploited in several different patterns.

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 to 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.

3.1. 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 Figure 4. 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 5. 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.

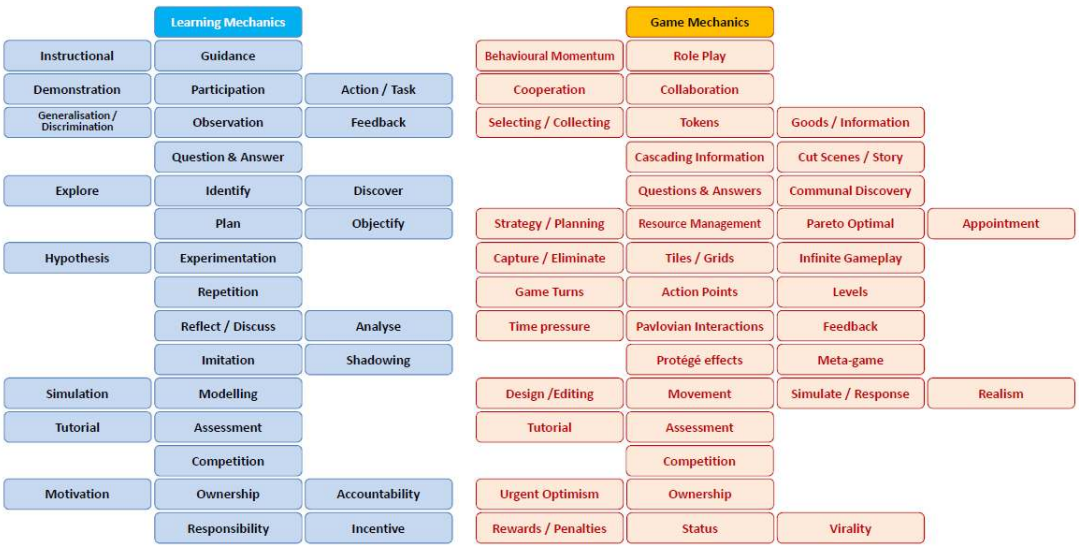

Figure 2. Learning and game mechanics used as the basis to construct the LM-GM map for a game

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; Gagné, Briggs, & Wager, 1992; Papert & 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, 2009b; Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012). Proper combinations of these mechanics may be applied in several SG application domains, from languages to science, humanities and arts.

Given the traits mentioned above, the authors argue that the LM-GM could be used to aid SG analysis (i.e., identifying and assessing the main features and components of a SG), design (i.e., thinking of what components could constitute a new SG) and specification (i.e., specifying the components of a SG and their relationships).

3.2. 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 (Figure 3) organised in line with the digital taxonomy of Anderson, Krathwohl, and Bloom (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.

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	

Figure 3. Classifications based on Bloom's ORDERED Thinking Skills

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., Figure 4) and show on a map their dynamic appearance during the game flow of actions (e.g., Figure 5).

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.

3.3. 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, Cole, Bradlyn, & Pollock, 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, Haritatos, & Cole, 2009; Wouters, van Oostendorp, Boonekamp, & van der Spek, 2011; Cole, Yoo, & Knutson, 2012; Mader, Natkin, & Levieux, 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 Figure 4, 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.

Figure 4. The LM-GM 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 5).

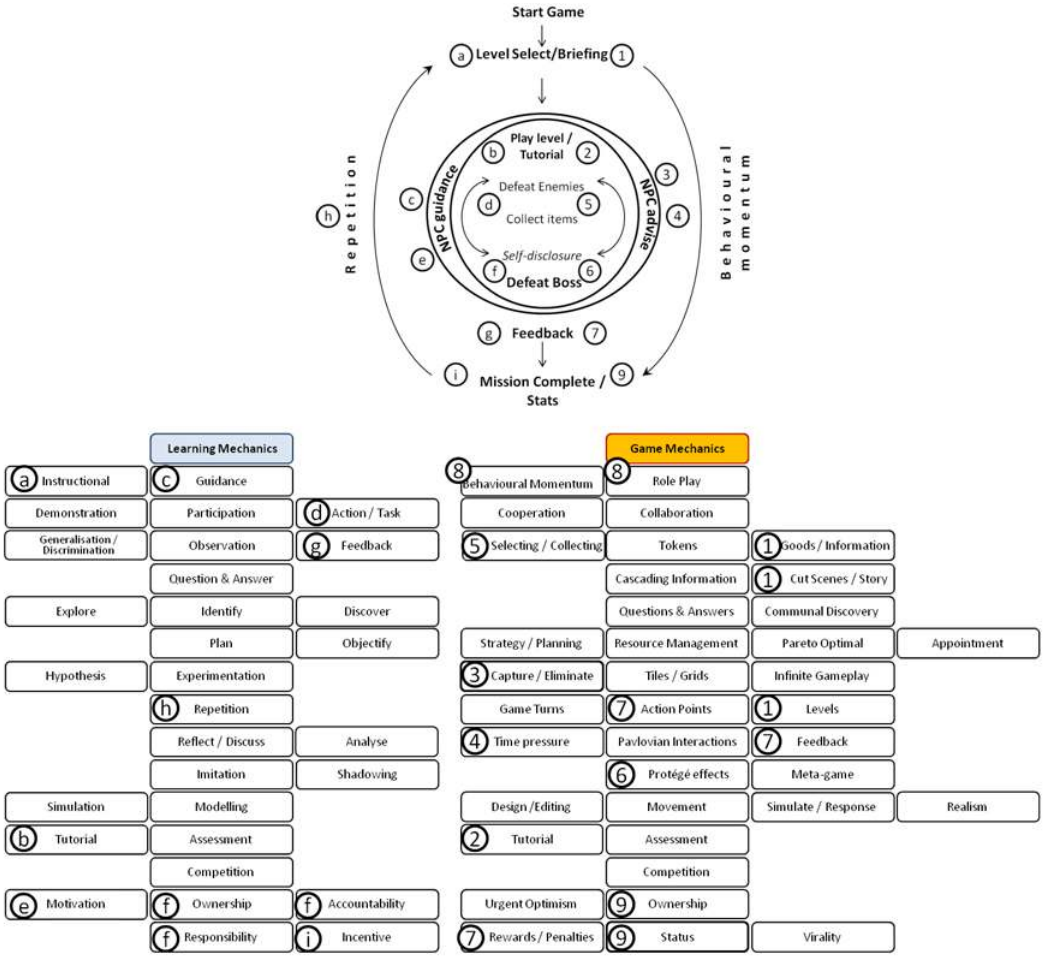

Figure 5. A game map constructed through an LM-GM-based analysis of Re-Mission

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.

3.4. Validation and Evaluation

In the following sections, we present the experimental results of tests we have performed to validate the use of LM-GM as a SG analysis tool. In particular, we discuss two user studies, the first one examining the effectiveness of LM-GM in comparison to a state-of-the-art model, namely Amory's updated GOM, and the second one evaluating users' acceptance of LM-GM.

GOM was chosen as its methodology was viewed as effective to describe the relationships between a pedagogical dimension of learning and its game elements. The diagrammatic mapping of the game- learning relationships in GOM was also considered as most complementary to LM-GM. We thus set up a comparison test to ascertain if LM-GM could address better the bridging between the pedagogical dimension of learning and its game elements; particularly the existence of SGMs. The evaluations were independently conducted and validated at two different hosting sites. The participants include a mix of academics, students and game developers from various countries, all of whom had some gaming experience.

The actual user evaluations were preceded by a comparison test to check whether the two models were comparable, as we demonstrate in the following.

4. COMPARISON OF LM-GM AND GAME OBJECT MODEL (GOM)

A fitness and comparison test was performed by 26 participants from UK, China and Mexico. Participants first identified the relationships between elements in the LM-GM framework considering the context of the SGM description; the outcome is presented in Figure 6. The SGM acts as the mechanism by which concrete learning activities are connected, as defined by the pedagogical patterns, to abstract design game elements. The abstract game layer represents game dynamics (e.g. achievements) as defined by game design patterns, which in turn can be mapped as a function of several Game Mechanics. This represents a many-to-one relationship between the abstract and concrete elements of game design and learning. A single abstract learning objective can be achieved by different learning activities and a single Game Dynamic can be achieved through several different Game Mechanics. It should be noted that the abstract and concrete elements have been identified with respect to Amory's model, literature findings and from objective responses by participants in the case study described in the previous section. Unlike Figure 3, the relationship diagram in Figure 6 is not ordered top down but simply represents elements considered to be abstract or concrete within LM- GM, without any sorting. Originally combined elements, such as fun, challenge, quick feedback and story, have been separated to provide better abstract and concrete discretization.

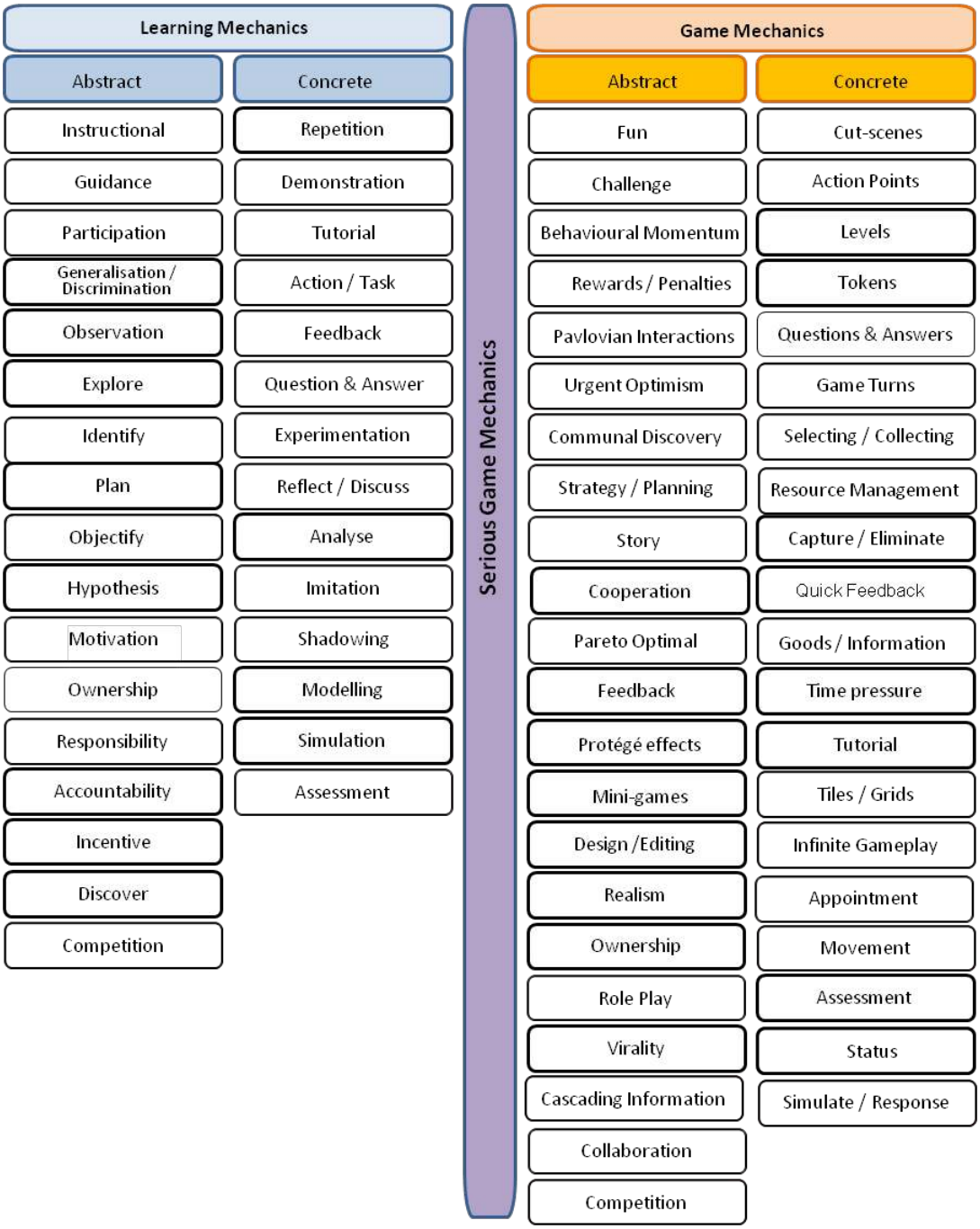

Figure 6. Abstract and concrete elements of LM-GM framework and the SGM interface

Once we established that the models are comparable, we could assess the effectiveness of each model in supporting users in evaluating serious games. It is important to highlight that the goal of the experiment was not to evaluate the participants' ability to analyse a game, but to have them assess the two different models by concretely applying it. This was clearly stated to all the participants prior to the tests.

4.1. User evaluation 1

The first user test was designed to evaluate how effective each model was in enabling users to analyse game-play and purpose of SGs, and in particular to determine to what extent the models facilitated the recognition of connections between game mechanics and pedagogical intentions.

Two games were used in this user study: the already mentioned *Re-Mission* and Serious Games Interactive's *Playing History: The Plague* (www.playinghistory.eu), a role playing game in which the player explores medieval Florence in search of a cure for the plague, experiencing history and the living conditions from that time through the eyes of the protagonist.

Ten students (9 males, 1 female), with ages varying from 21 to 40 years old (M=25.7, SD=5.46), were recruited to participate in the study. All of them were pursuing their Bachelor or Master degrees in Electronic Engineering in Italy at the time. The majority of the participants (80%) reported being at least somewhat familiar with games in general. Familiarity with serious games, on the other hand, was not so high: 70% of the participants declared low or very low familiarity with this specific type of games.

For the analysis, participants were divided equally into two groups. Both groups played the first game, *Re-Mission*, and were then asked to complete an open-ended questionnaire about their understanding of the purpose of the game and their understanding of how well the game supported learning in each of Bloom's revised taxonomy categories (remembering, understanding, applying, analysing, evaluating and creating) (see Figure 3; Anderson et al. (2001)). This was done to establish a baseline of their understanding of the game. Subsequently, the first group received an account on how to evaluate a game using the list of components identified by the Game Object Model (Amory, 2007), while the second group received an explanation about the LM-GM model. Both groups were asked to perform an evaluation of *Re-Mission* using their assigned model. After performing the analysis, participants were asked to complete the same questionnaire, being instructed to change their answers if they felt they had new insights on the game after analysing it using the model presented to them. The same procedure was repeated with the second game, *Playing History: The Plague*, inverting the models assigned to each group. At the end of the study, participants were asked to make comments about both models. Figure 7 illustrates the workflow for each group.

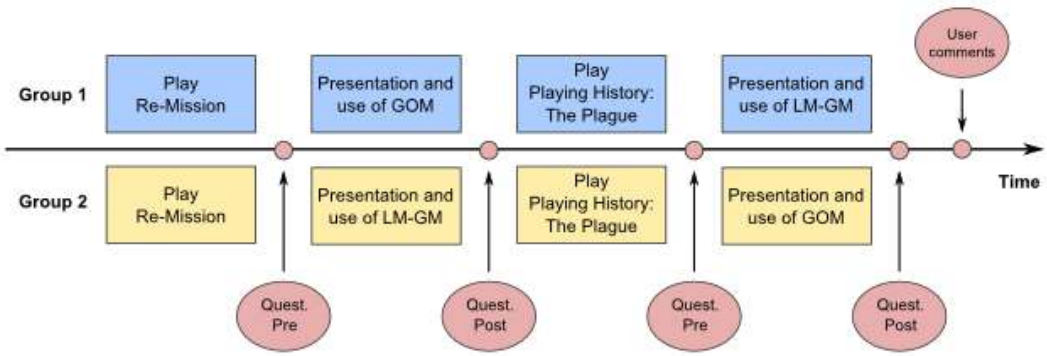

Figure 7. Timeline of the comparison study between LM-GM and GOM

Two evaluators rated the participants' responses independently in a scale from 1 to 5, according to the following criteria: *clarity; appropriateness; presence of examples to illustrate answers; ability to identify game mechanics; ability to identify learning intentions and outcomes; and ability to identify connections between game mechanics and learning mechanics*.

It was identified that three participants were seemingly tired or uninterested, for their answers were judged as unmindful or careless by both evaluators. Those three cases were ignored in the analysis. In addition, the question regarding creation of new content (the uppermost level of Bloom's taxonomy) was largely misunderstood by participants and was also disregarded in this study.

Ratings from both evaluators were averaged for each question. Next, the scores for all questions were averaged again to obtain one score for each participant in each one of the conditions (pre GOM, post GOM, pre LM-GM and post LM-GM). The resulting values are shown in Table II below.

Table II. Average scores for open-ended questions, before and after the analysis with each model

Participant	Pre GOM	Post GOM	Pre LM-GM	Post LM-GM
1	2.63	3.83	2.33	3.92
2	1.75	1.75	2.38	2.67
3	2.33	2.71	2.21	2.33
4	1.83	1.83	2.25	2.29
5	3.17	3.17	2.54	2.75
6	2.88	3.08	2.67	3.29
7	3.25	3.46	3.25	3.25
Mean	**2.55**	**2.83**	**2.52**	**2.93**
St. Dev.	**0.61**	**0.79**	**0.36**	**0.59**
Median	**2.63**	**3.08**	**2.38**	**2.75**

A Wilcoxon matched pairs signed rank test was conducted for each of the two models, comparing before and after scores. For the Game Object Model, because of the small sample size and the number of repeated scores, the test could not determine any significant difference between conditions (T= 0, p = 0.125, two-tailed test, N = 4). On the other hand, for LM-GM the same test indicated that participants improved their scores after performing the analysis of the game (T= 0, p = 0.031, two-tailed test, N=6). The Wilcoxon matched pairs signed rank test excludes pairs of samples with zero difference (entries shaded in Table II), effectively reducing the sample size N in the pre and post conditions to 4 and 6, respectively.

Although the sample size of this study was too small to provide conclusive results, this exercise enabled us to draw preliminary conclusions regarding the effectiveness of both models. While GOM allows users to reflect over quite general characteristics of the game, LM-GM appears to invite users to focus on lower level mechanics of the game-play. On the other hand, LM-GM seems to be more complicated to be understood, in particular by novices. Nevertheless, LM-GM seems to support better the recognition of the connections between game and learning mechanics, even if in a simple way. In addition, LM-GM seems to have a higher educational value, supporting learning as it familiarises users with the terminology and concepts that are fundamental for understanding games (e.g. protégé effect, role play, game turns, infinite gameplay). As one participant put it, "*the [LM-GM] method is a bit more difficult to understand, but more adequate to answer the questions; the [Game Object Model] is simpler and more descriptive, but did not make me change my [understandings on how the game supported learning]*".

4.2. User evaluation 2

In the second user study, 26 individuals (13 UK, 10 China, and 3 Mexico) were consulted regarding their perceptions on the usefulness of each model. The analysis of the game was performed by a mix of academics, students and game developers all of whom had some gaming experience. They analysed the game-play independently using the LM-GM and GOM, and their analysis was combined and summarised in Figure 4 and Figure 5. Table III presents a brief summary of the participants' appreciation of the LM-GM and Amory's GOM based on this activity.

The experimental protocol was as follows:

1. Participants were provided information regarding the LM-GM nodes (Lim et al., 2013) and the GOM (Amory, 2007).
2. Participants had no training on using the LM-GM or GOM other than a sample and basic explanation on the flow of the nodes. This was intentional as the objective was to ascertain the ease of using/interpretation of the LM-GM and GOM models.
3. Participants were informed that a synopsis of the game was available through the game's website. This was to cater for participants outside UK.

4. Participants were given four weeks to play and reflect on the game, and to produce the LM-GM and GOM mappings. All participants analysed the Re:Mission game-play independently and twice, once applying LM-GM, once GOM. To avoid order effects, half the participants applied LM-GM first and half GOM first.
5. Participants complete a System Usability Scale (SUS) report, which is well established a tool used in usability engineering (Brooke, 1996). The SUS report comprises 10 questions, that we employed for both the LM-GM and GOM.
6. An interview was conducted upon receiving their LM-GM/GOM mapping and SUS report.

It is important to note that SUS scores for individual items are not meaningful on their own. The scoring of SUS requires a composite measure of the overall usability. For LM-GM, with 26 participants, the SUS average is 67.3. GOM SUS average was 46.7.

In agreement with the findings of the first study, the majority of the participants felt GOM was much easier to use but conversely found that it did not allow basic pedagogical and game patterns to be identified. A key reason was GOM's overlapping 'spaces', which did not illustrate the flow of the game-learning elements. This is supported by the responses that participants gave when queried about the ability of GOM to link learning and game intent. The observations suggest that GOM is somewhat superficial and does not take the flow of game play into account. The fact that participants considered GOM easier to understand although being less effective points to the direction that the LM-GM model should be made easier to apply, providing better description of the utilization workflow.

Two participants with some experience in developing engineering games provided succinct feedback during the interview highlighting that GOM *"does not address how to implement learning objectives or to enable mapping of learning mechanics to game mechanics" and that "I can't see where GOM enables core instructional design to be made. The LM-GM has the advantage here."*

Table III. User appreciation of LM-GM and GOM

Identifying game mechanics (user evaluation 2-1)						
	Ease of use	Recognition of basic game rules	Association with core concepts	Interface between learning mechanics	Able to elicit basic game pattern	Link to learning
Amory	60 %	40 %	37 %	45 %	25 %	36 %
LM-GM	40 %	60 %	63 %	55 %	75 %	64 %
Identifying learning mechanics (user evaluation 2-1)						
	Ease of use	Recognition of learning activities	Association with core concepts	Interface between game mechanics	Able to elicit basic pedagogical pattern	Link to game intent
Amory	60 %	45 %	40 %	45 %	35 %	45 %
LM-GM	40 %	55 %	60 %	55 %	65 %	55 %

To prevent bias with the mix of participants (i.e. the assumption that academics and game developers would fare better than people with no game analysis/design experience), a second study was solely conducted with students of an unrelated field. The demographic comprised 25 final year Engineering students, with limited game analysis experience. The same protocol described previously was used and the results are tabulated in Table IV. A scanned result of one of the mappings is showed in Figure 8. The hypothesis is that given their experience in systems design and engineering analytics, they would be able to apply that knowledge together with the supporting material (in protocol step 1) to use the LM-GM and Amory to map the process of game play and learning elements in *Re:Mission*.

As with the first evaluation, half of the participants started with LM-GM, half with GOM. Comments from this second evaluation pointed clearly that some prior knowledge for using LM-GM would be useful; however, the material provided with LM-GM did indeed help them use the model. When queried on the 'ease of use' it turns out that the LM-GM informative material supplied

Table IV. Second User appreciation of LM-GM and GOM. Participants comprise only of students with limited game analysis experience

	Identifying game mechanics (user evaluation 2-1)					
	Ease of use	Recognition of basic game rules	Association with core concepts	Interface between learning mechanics	Able to elicit basic game pattern	Link to learning
Amory	52 %	30 %	40 %	35 %	20 %	32 %
LM-GM	48 %	70 %	60 %	65 %	80 %	68 %
	Identifying learning mechanics (user evaluation 2-1)					
	Ease of use	Recognition of learning activities	Association with core concepts	Interface between game mechanics	Able to elicit basic pedagogical pattern	Link to game intent
Amory	50 %	40 %	33 %	40 %	25 %	35 %
LM-GM	50 %	60 %	67 %	60 %	75 %	65 %

meant much reading, compared to the GOM, which operates at a much higher level. Hence, LM-GM scored lower. Interestingly, all the participants found that the LM-GM node descriptors actually helped them carry out the GOM mapping better.

The LM-GM SUS average for this second evaluation was 71.4. GOM SUS average was 43.7. Comparing to the first evaluation, it confirms that the LM-GM is more capable than GOM to support game analysis and the difference is even stronger in a population not expert of game analysis/design.

Although there are missing components in both the LM and the GM, these initial results reveal that the LM-GM is able to provide insights into the pedagogical and gaming patterns of a game. This work presents the first step in completing the larger puzzle and providing game designers and educators a more practical conceptual tool to effectively implement educational mechanisms in SGs.

5. CONCLUSIONS AND FURTHER RESEARCH

The main focus of this paper was to discuss the definition of the mechanics of serious games towards providing a more systematic view of the relationship between pedagogical principles and game elements. In our work, we have found that SG design has been linked with entertainment game design, particularly in the context of adopted game mechanics. In particular, our work has revealed particular strengths of some game mechanics that are typical of entertainment games and are also suited for serious and educational games.

This paper reports studies that were performed using the LM-GM model – a framework we have developed for Serious Game Mechanics analysis – that addresses the mismatch between game mechanics and educational components/aims. We demonstrated through a case study how LM-GM could support the evaluation of SGs, enabling the recognition of low-level game mechanics and their connections to pedagogical intentions. We also described the results of a comparative study between the LM-GM model and the state-of-the-art Game Object Model (GOM) framework, reporting on LM- GM's effectiveness and users' appreciation of its usability and usefulness.

Beside the content presentation aspect, which is covered in the LM-GM's current version, effective SGs for education and training also demand proper user assessment, in order to allow meeting the educational goals and provide appropriate user feedback (De Gloria, Bellotti, & Berta, 2012). Stealth or embedded assessment looks particularly effective, as it allows evaluating the player without breaking the flow experience (Shute V. J., 2009). Thus, we plan to upgrade the LM-GM model concerning the support of mechanics for in-game assessment (Bellotti et al., 2013). The LM-GM does not consider a player model yet. However, adaptation and personalization are key factors for education (Bellotti, Berta, De Gloria, & Primavera, 2010a). Thus, inserting this new dimension in the model is a significant challenge for the future research.

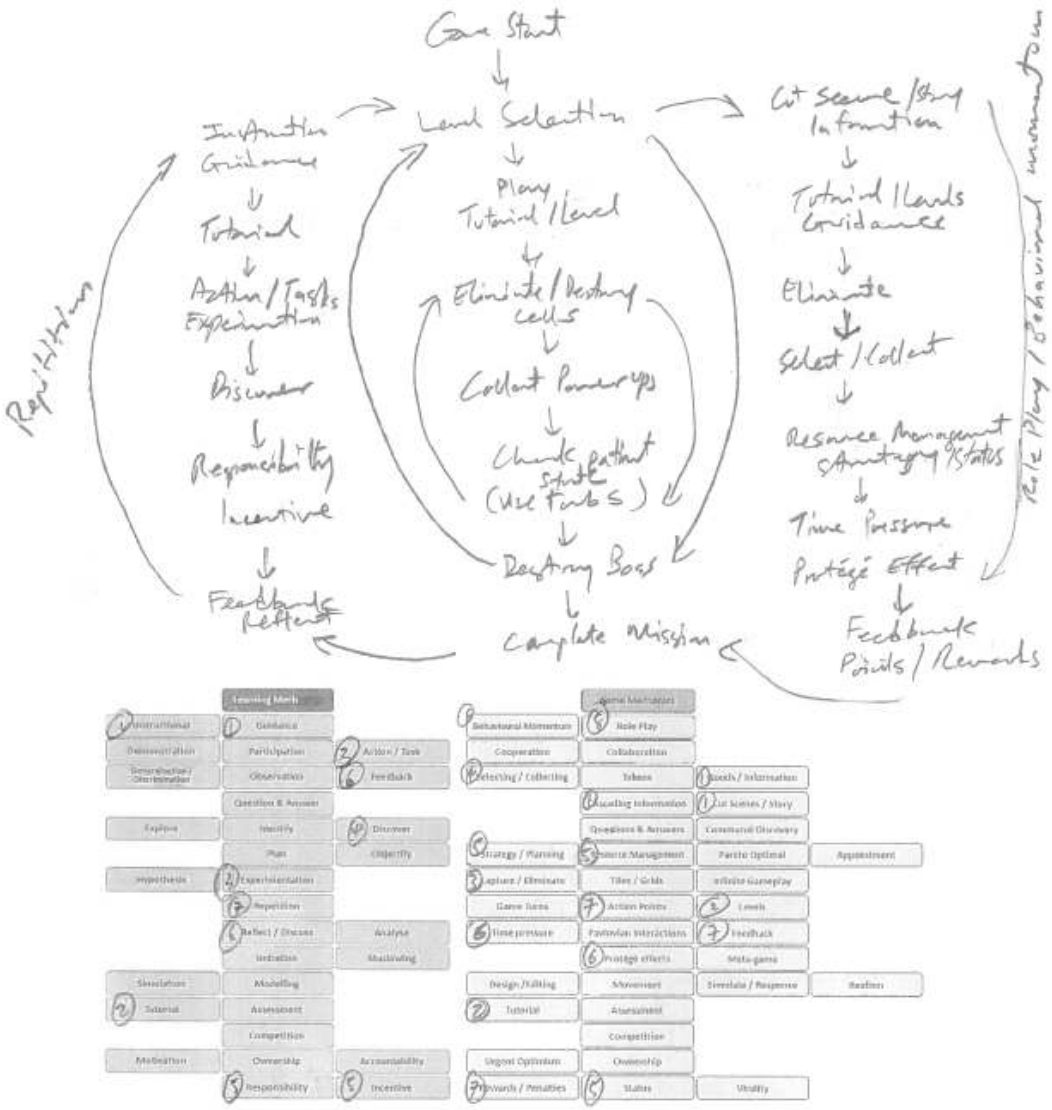

Figure 8. LM-GM and GOM mapping from participant (P14) during usability study

The LM-GM framework has the ambitious goal of becoming a general tool that can be employed by game designers and domain-expert (including teachers) interested in developing and/or analysing SGs. The earlier version of LM-GM has been considered in the design and analysis of a game called PR:EPARe (Arnab et al., 2013), which demonstrates the potential for it to be used to aid and inform game design. However, the scope of this tool in its present state is still limited. In this paper, in particular, we have shown its validity as a SG analysis tool. Further work includes refining the LM-GM with regards to the development of its prescriptive aspect, which involves suggesting preferential mapping of learning goals to game mechanics. This is being prepared through extensive SG studies that are being carried out within GALA (Bellotti et al., 2012) – capitalising on a

knowledge management system dedicated to SGs and based on a SG taxonomy (Popescu & Bellotti, 2012) – and should enhance the framework's effectiveness as a design tool, meeting the emerging requirements from developers and stakeholders Another challenging addition will be the inclusion of a neurophysiological analysis of a user behaviour during game play (Berta, Bellotti, De Gloria, Pranantha, & Schatten, 2013). Finally, appropriate support for integrating the use of a game within a given curriculum should also be studied and specified.

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