

An activity theory-based model for serious games analysis and conceptual design

Maira B. Carvalho^{a,b,*}, Francesco Bellotti^a, Riccardo Berta^a, Alessandro De Gloria^a, Carolina Islas Sedano^c, Jannicke Baalsrud Hauge^d, Jun Hu^b, Matthias Rauterberg^b

^a*DITEN, University of Genoa, Via Opera Pia 11A, 16145 Genoa, Italy*

^b*Industrial Design, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, Netherlands*

^c*School of Computing, University of Eastern Finland, P.O.B. 111, FI-80101 Joensuu, Finland*

^d*Bremer Institut für Produktion und Logistik, University of Bremen, Hochschulring 20, 28359 Bremen, Germany*

Abstract

There are currently a number of models, frameworks and methodologies for serious games analysis and design that provide useful interpretations of the possibilities and limitations offered by serious games. However, these tools focus mostly on high-level aspects and requirements and do not help understand how such high-level requirements can be concretely satisfied. In this paper, we present a conceptual model, called Activity Theory-based Model of Serious Games (ATMSG), that aims to fill this gap. ATMSG supports a systematic and detailed representation of educational serious games, depicting the ways that game elements are connected to each other throughout the game, and how these elements contribute to the achievement of the desired pedagogical goals. Three evaluation studies indicate that ATMSG helped participants, particularly those with gaming experience, identify and understand the roles of each component in the game and recognize the game's educational objectives.

Keywords: Serious games, educational serious games, serious games analysis, serious games design, activity theory

*Corresponding author

Email address: m.brandao.carvalho@tue.nl (Maira B. Carvalho)

1. Introduction

Several studies indicate that games can provide an enhanced experience compared to more common teaching methods (Bellotti, Berta and De Gloria, 2010; Knight et al., 2010; Kebritchi et al., 2010; Guillén-Nieto and Aleson-Carbonell, 2012; Kickmeier-Rust and Albert, 2012; Erhel and Jamet, 2013) and thus have a potential as a learning tool, but how this actually happens is still not fully answered (Van Staaldouin and de Freitas, 2011).

In an attempt to uncover the reasons behind the success or failures of educational serious games, researchers have developed models, frameworks and methodologies to investigate and analyze games (Amory, 2007; Arnab et al., 2014; Bellotti, Berta, De Gloria and Primavera, 2010; De Freitas and Oliver, 2006; Gunter et al., 2006; Van Staaldouin and de Freitas, 2011). These works provide interpretations of the possibilities and limitations offered by serious games and explain, at a high-level, why games are motivating, enable learning by doing, or bring a social component to learning. However, they do not fully answer the question on how the concrete components of the game have to be structured to support learning. We want to go more in depth with the development of conceptual tools to aid serious game analysis and design, principally linking entertainment mechanics and learning goals (Bellotti et al., 2012; Greitzer et al., 2007). In particular, we stress the importance of understanding how concrete components of a serious game can be defined, used and combined to support efficient learning.

In this paper we propose a new model to investigate how a serious game connects educational and entertainment high-level objectives with low-level in-game components on one hand, and how it links individual gaming and pedagogical components as the game unfolds on the other. The model, named Activity Theory-based Model of Serious Games (ATMSG), is based on concepts of activity theory, a line of research in the social sciences that studies different forms of human practices and development processes (Jonassen and Rohrer-Murphy, 1999). Activity theory offers a structured framework that considers the game not as an isolated tool, but as part of a complex system that also includes human actors (player or learner, instructor and game designer) and the motives driving their interactions with the game.

The ATMSG model includes a serious game components taxonomy, which is based on established taxonomies of learning, of instructional design and of game components. The taxonomy, used in conjunction with the model, supports the analysis of serious games by providing an extensive list of commonly found structures. This list can be referred to when trying to identify the various components that constitute serious games.

The ATMSG model may also be used as a tool for conceptual design of serious games. Being applied at early stages of prototyping, the model helps serious game designers in assessing if the envisioned game structure is able to support the desired pedagogical goals.

This work is targeted at two main user groups. First and foremost, to those involved directly in the study and creation of games for learning, namely serious games researchers and serious games designers, who possess a high level of knowledge on the topic. The second group consists of non-expert users involved in a serious game design or evaluation project, and who find themselves in need of understanding serious games in more depth, e.g. entertainment game de-

signers, educators or people with knowledge in a topic addressed in the project (domain experts).

2. Theoretical background

Activity theory is the line of research initiated in the 1920s and 1930s by a group of Russian psychologists, notably Vygotsky and Leont'ev (Engeström, 1987). It studies different forms of human practices and development processes, providing a model of humans in their social and organizational context (Hasan, 1999). Despite the popularity of activity theory in the fields of learning and instructional design, only a few studies apply directly the most prominent elements of the theory to the study of games and serious games (Marsh, 2006; Zaphiris et al., 2010; Peachey, 2010; Islas Sedano, 2012). Related concepts, such as that of Zone of Proximal Development, by Vygotsky, are more commonly applied in serious games studies, often combined with the Flow theory (Csikszentmihalyi, 1990).

In activity theory, the basic unit of analysis of all human endeavors is activity: a purposeful interaction between subject and object, in a process in which mutual transformations are accomplished. This interaction is usually mediated by physical tools (knives, hammers, computers) or mental tools (notations, maps), which shape the way humans interact with the world (Kaptelinin and Nardi, 2006).

Engeström (1987) extended the original model of activity proposed by Leont'ev (1978), describing the activity as a collective phenomenon. The model, called Activity System, is depicted as a triangle (Figure 1) in which the sides represent the main components of the system (subject–object–community) and the corners represent the mediation artifacts to those relationships (tools–social rules–labor division). The activity is directed at the object and results in an outcome. Years later, Engeström (2001) extended the model to also represent multiple perspectives and dialogs between several interacting systems (Figure 2). This second model is called Activity System Network (Engeström, 2001; Guy, 2005).

According to activity theory, an activity happens simultaneously at three levels, in a hierarchical structure (Figure 3) (Kaptelinin and Nardi, 2006, ch. 3). At the topmost level, the *activity* is directed at a *motive*; in other words, the motive is the object that the subject ultimately wants or needs to attain. Typically, the *activity* is realized by a sequence of *actions*, each of which may not be directly related to the motive (Kaptelinin and Nardi, 2006; Devane and Squire, 2012). Each *action* is also directed at an object: the *goal*. The subject is typically aware of his goals, but maybe not consciously aware of his motives. On its turn, an action is also composed of lower-level units, called *operations*, which are performed unconsciously, according to given *conditions*.

The activity is not a static entity. Constant transformations happen between the levels, according to changes in the environment or in the subject's motivations or skills (Kuutti, 1995; Peachey, 2010). Furthermore, it is possible to realize the same activity by different sets of actions and operations, and the same actions can be part of different activities simultaneously (Hasan, 1999).

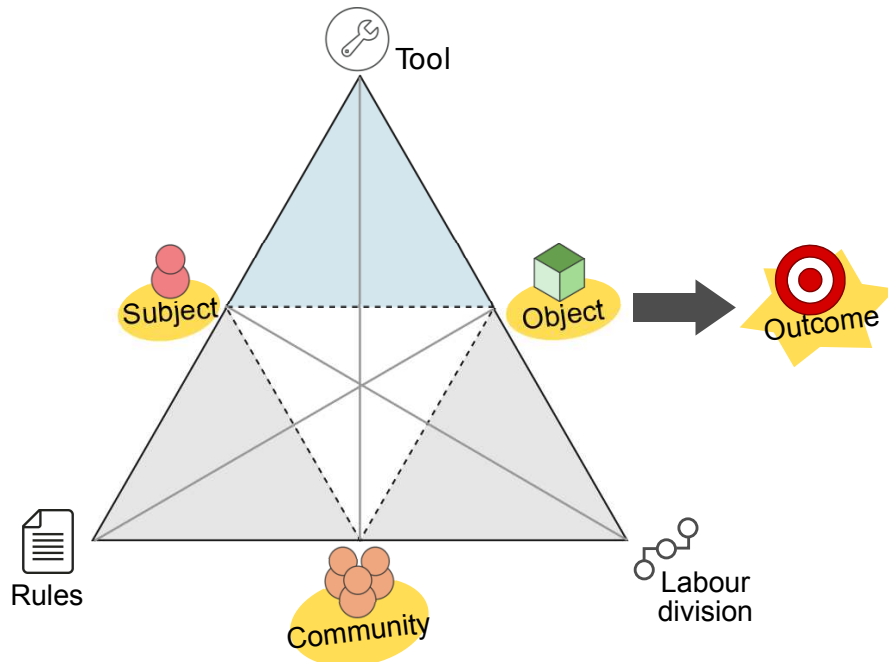


Figure 1: The Activity System, proposed by Engeström (1987)

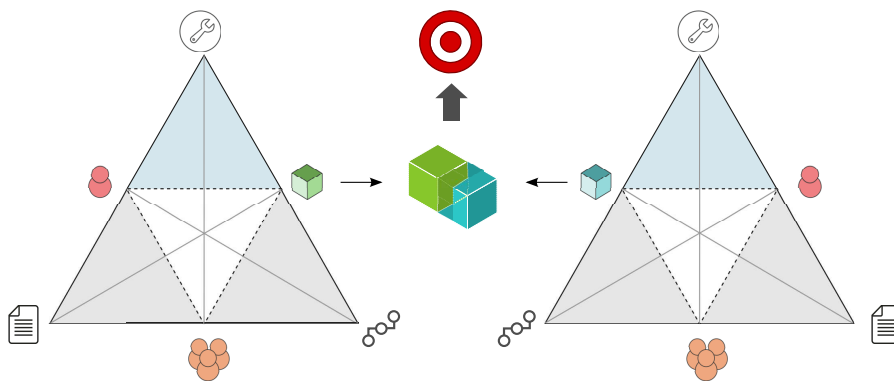


Figure 2: The Activity System Network (Engeström, 2001)

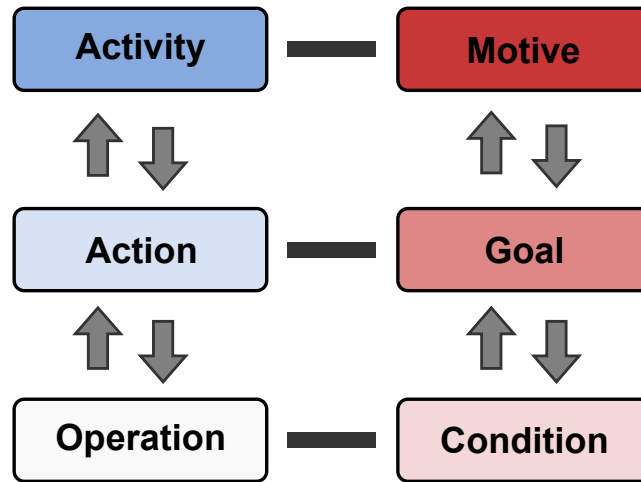


Figure 3: The hierarchical structure of activity, or levels of activity, as defined in activity theory

3. Related work

Several existing frameworks, models and methodologies that investigate both entertainment games and serious games were examined, in order to evaluate how well they support the understanding of the deeper relationships between different components in educational serious games.

The *MDA framework* (Hunicke et al., 2004) proposes three perspectives from which to understand and design games: the actual implementation of the game (Mechanics), the overarching design goals (Dynamics) and the resulting player’s experience (Aesthetics). *MDA* is aimed at games in general, consequently it does not explicitly support reasoning about the educational elements in a serious game. The *Hierarchical Activity-Based Scenario (HABS)* framework (Marsh, 2006, 2010) also examines games using a layered perspective, but from the point of view of the game’s narrative and players’ experiences and behaviors. *HABS* uses activity theory to help designers in defining levels of the user experience when modeling game scenarios and narratives. Marsh and Nardi (2014) later expanded the framework to account for user engagement and entertainment including interactions that extend beyond the game world. *HABS* provides valuable support for developing a high-level set of ideas and concepts for gameplay (Marsh, 2010). Nonetheless, it does not account explicitly for the interaction between gaming and learning, nor does it represent specific elements that form the serious game.

While *MDA* and *HABS* deal with the relationships between different layers of implementation of the game, other frameworks and models focus on the description of low-level components. Koster (2005) and Bura (2006) attempted to define a compact visual language for communicating underlying principles of games. Inspired by their work, Djaouti et al. (2007) created a diagram language to formally deconstruct videogames into “game bricks”. The framework *Machinations* (Adams and Dormans, 2012) describes a dynamic graphical notation representing games as rule-based systems (Dormans, 2009). The *Game Ontology Project (GOP)* (Zagal et al., 2005) defines a hierarchical representa-

tion of the important structural elements of games in an attempt to establish a common vocabulary to the field. All these works complement each other and contribute to the effort of creating formal, precise, and scalable descriptions of games and gameplay (Sicart, 2008). However, they are limited to describing games in general, without incorporating educational elements.

We also reviewed models that looked specifically at the educational value of serious games. The *Four-Dimensional Framework* (De Freitas and Oliver, 2006) postulates four dimensions of learning processes that need to be considered: learner modeling and profiling, the role of pedagogic approaches for supporting learning, the representation of the game, and the context in which learning takes place. The *RETAIN model* (Gunter et al., 2006) aims at determining whether a serious game is appropriate for educational purposes, how well the pedagogical content is embedded in the game’s narrative and how it promotes knowledge transfer. The *Experiential Gaming Model* proposed by Kiili (2005) assigns central importance to linking experiential learning and gameplay theory, since this connection facilitates the flow experience and has positive impact on learning. The *Game-based Learning Framework* (Van Staaldunin and de Freitas, 2011) also focuses on immersive learning experiences, with a structure that resembles Kolb’s experiential learning cycle (Kolb, 1984). These give a general understanding of a serious game, facilitate the comparison with other similar games and possibly help determine how well the serious game fits an educator’s needs. The main limitation of the aforementioned frameworks is that none of them investigate the actual elements of the game.

However, there are works that investigate serious games in a more fine-grained manner. The *Game Object Model II (GOM II)* (Amory, 2007) describes the relationships between game and pedagogical elements using the metaphor of interfaces in the Object Oriented Programming paradigm: abstract interfaces are theoretical constructs and pedagogical goals of the game, while concrete interfaces are the design elements that realize the goals. However, *GOM* does not represent how the relationship between game elements develops over time, and its diagram can become complex and difficult to understand. The *Learning Mechanics–Game Mechanics (LM–GM)* model (Arnab et al., 2014) provides a graphical representation of the game flow as the basis for establishing the relationships between the components that translate pedagogical practices (“learning mechanics”) into concrete game mechanics. The authors call “Serious Game Mechanics (SGM)” the identifiable abstract patterns that can be replicated across serious games. *LM–GM* features a clear graphical representation of the game flow and a predefined list of elements to support the analysis. A limitation of *LM–GM* is that it does not expose the connection between concrete mechanics and the high-level educational objectives that the game is supposed to attain.

Still with the objective of supporting serious game design, some authors compiled libraries of commonly reoccurring patterns (Kiili, 2010; Games Enhanced Learning, 2010; Marne et al., 2012). However, these libraries neither offer the classification of individual components nor an account of the relationship between them.

From the analysis of the related work, we identified that existing methods, methodologies and frameworks for serious games analysis and design are either focused only on high-level aspects of serious games, or they offer a way to investigate the inner components of the game but without providing a clear

connection between the concrete mechanics and the high-level objectives of the game. In this work, we aim to address this issue by proposing a modification of the *LM-GM* model, expanding it to incorporate high-level aspects of the serious game to the analysis using concepts of activity theory, as will be explained in Section 5.

4. Research approach

To elaborate the Activity Theory-based Model of Serious Games (ATMSG) and the taxonomy of serious games components, we performed an iterative process that alternated between literature review and practical testing of the concepts to identify points for refinement.

The survey on methods, methodologies and frameworks for game and serious game design showed the missing links and gaps that should be addressed, as discussed in Section 3.

We used activity theory to understand the context of use of educational serious games, by identifying the relevant network of activities (as proposed by Engeström (2001), see Section 2). We investigated five games of different genres and different learning domains (*Darfur is Dying*, *DragonBox*, *Go Venture CEO*, *IBM City One* and *Playing History: The Plague*). From this step, we derived the ATMSG model, presented in Section 5.

A new literature search was performed to find reference frames to help users in identifying game components according to activity theory. Since we could not find a unified taxonomy with the format we needed, we combined existing taxonomies of games, of learning objectives, and of instructional design theories into a new structure. The result of this step is described in Section 6.

Subsequently, we produced a first set of guidelines on how to apply the ATMSG model and the taxonomy for analyzing serious games. In a user-centered design approach, these guidelines have been iteratively improved during its elaboration, through a set of user tests, described in Section 8. The objective was to assess both the usability and the functionality of the model, in particular its capability to support the evaluation of the educational quality and effectiveness of serious games. We identified weak and strong points of ATMSG and used the results to simplify the model, resulting in the version that we describe in this paper.

5. Activity Theory-based Model of Serious Games (ATMSG)

In this section, we present our conceptual model derived from an activity-theoretical view of educational serious games, called the Activity Theory-based Model of Serious Games (ATMSG). This model utilizes the conceptual framework of activity theory to understand the structure of educational serious games, providing a way to reason about the relationships between serious games components and the educational goals of the game.

In the ATMSG model, we do not consider the game as an isolated artifact. Instead, we propose that the serious game and those using it to learn or to teach something are seen as part of a complex, dynamic system. From this perspective, educational serious games are typically used in the context of at least three activities: the gaming activity, the learning activity and the instructional activity (Figure 4).

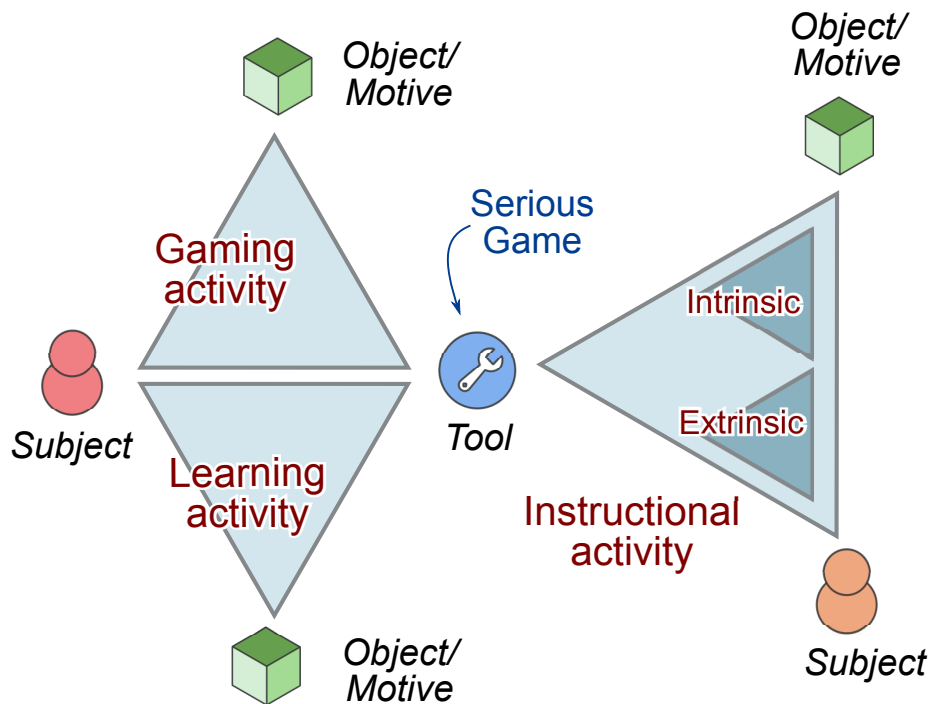


Figure 4: The ATMSG model: there are three main activities involved in the use of serious games for education. This figure represents the higher level of the activity system involved.

Figure 4 depicts the three main activities and the relationships between people and artifacts in this system. It is possible to see that the gaming and the learning activities share the same subject (the player/learner) and tool (the serious game), but they have different driving motives. For example, the motive driving the gaming activity might be simply to have fun, while the motive driving the learning activity might be to fulfill a course requirement. The instructional activity also shares the same tool, but has a different subject (the instructor and/or the game designer) and motive. A motive for the instructor might be, for example, to use the serious game to raise the learner's interest about the topic.

The difference between the learning and the instructional activities is important: while the learning activity corresponds to the point of view of the learner, the instructional activity depicts the side of the instructor(s). Acknowledging this distinction allows us to identify possible conflicts in motives driving the activities which might affect the learning outcomes of the game. It can also help in evaluating to which extent the instructional components of the serious game really support the stated learning outcomes.

Some educational serious games can be used by a learner on his own, while other games may also count on complementary activities led by an instructor. The ATMSG model explicitly accounts for this distinction, in order to clarify the role of the teacher/instructor in the game. For this reason, the instructional activity is subdivided in two activities: intrinsic instruction, and extrinsic instruction. The intrinsic instructional activity takes place solely inside the game.

It involves how the game itself supports learning (e.g. via tips, help messages, automatic assessments, in-game adaptive features). The extrinsic instructional activity, conversely, is performed outside by the teacher/instructor before, during or after the playing session, in the context of the overall learning setting (e.g. class, workshop, course, etc.).

In the intrinsic instructional activity, the subject is the game designer or producer, who “acts” in the serious game by means of design decisions made when creating the game, or via in-game assessment and feedback mechanisms. An analysis of this activity can be performed without necessarily considering a specific context of use. An analysis of the extrinsic instruction of a game, conversely, is heavily dependent on how the instructor uses the game. Consequently, such analysis cannot be carried out without explicit reference to a concrete usage setting.

The hierarchical structure of the activity, as defined in activity theory, gives us the ability to change the focus of the analysis to different levels of detail. This approach has been used previously by the *HABS framework* in the study of games and serious games (Marsh, 2006, 2010; Marsh and Nardi, 2014), providing a useful and flexible tool to analyze and design interaction and gameplay. It also provides a way to reason about the player/learner’s engagement, by looking at how much the motives driving all three activities coincide or not, and how much these motives coincide with the goals of the actions (Marsh and Nardi, 2014). In ATMSG, we expand this hierarchical analysis: we also divide the activities into actions, and the game itself into its smaller pieces. Specifically, each activity is broken down into a sequence of actions mediated by tools with specific goals. Like the activity, actions can also be depicted as triangles, as shown in Figure 5.

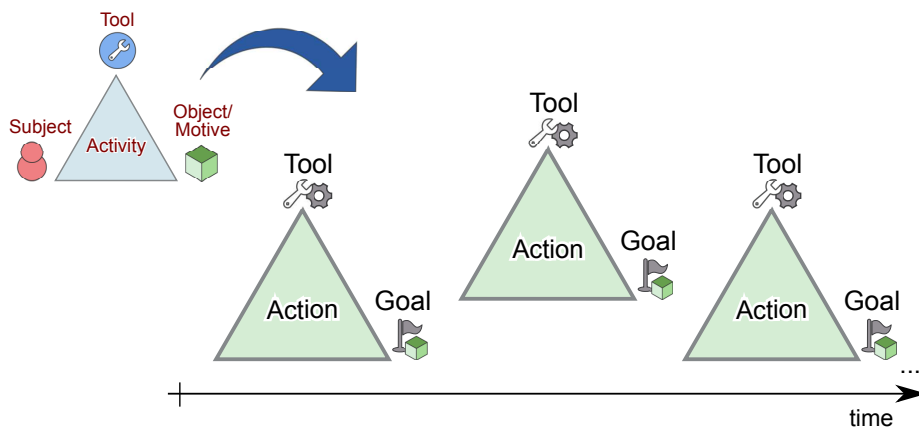


Figure 5: Each activity is formed by a sequence of actions. These actions mirror the triangle of activity: they are also mediated by tools, with specific goals

We call the items that form these smaller triangles “serious games components”. Serious game components are the concrete pieces of a serious game, e.g. characters, tokens, tips, help messages, etc. They can be classified as gaming, learning or instructional components, according to the activity they support. To show the relationships between the components of the different activities over time, the triangles can be represented in an alternative way: flattened, as

nine (or twelve, if considering the extrinsic activity) layers of components that interact over time during gameplay (see Figure 7 for an example of these layers). There can be overlaps, as one component can support actions from any of the activities simultaneously. For example, a puzzle-type challenge can play a role as a game component, as a learning tool and as an instructional tool at the same time.

Actions can also be broken down into their constituent operations. At this level, a serious game is seen as a combination of its low-level components (buttons, graphics, sounds, menus, etc.), which mediate operations performed unconsciously by the subject (reading a text, clicking a button, etc.). The ATMSG model does not explicitly consider this level of analysis, since there are no significant differences on how digital serious games and other software are constituted at this level. Hence, existing frameworks for applying activity theory in Human-Computer Interaction (HCI) research (Kuutti, 1995) and in usability studies (Kaptelinin, 1996) can also be used to analyze serious games at this level of detail.

6. Taxonomy of serious games components

We used the ATMSG model (Section 5) to reorganize existing taxonomies of learning, instruction, games and serious games into a unified vocabulary that can be easily consulted when needed. It aims to aid in the identification and classification of components according to their characteristics and roles in the game.

The taxonomy is organized in a tree structure in which items are classified according to the activity to which they belong, and, within the activity, categorized as actions, tools or goals. These categories are described below.

6.1. Gaming components

The list of gaming components incorporates terms described by previous works on game mechanics (Adams and Dormans, 2012; Djaouti et al., 2007; Koster, 2011; Schell, 2008; Zagal et al., 2005), in addition to the game mechanics identified in the LM-GM model (Arnab et al., 2014) and the game components of the GOM II model (Amory, 2007).

There are a number of different definitions of “game mechanics” (Sicart, 2008). To avoid confusion with existing terminology and inconsistencies in the definitions, we do not use this term. Instead, we classify gaming components according to the three layers of the gaming activity, i.e. actions, tools and goals. These are roughly equivalent to what has typically been defined as game mechanics by game researchers and designers.

The components classified as *gaming actions* (Table 1) describe, from the player’s point of view, which actions can be performed in the game at any given point. They have been grouped in categories that express similar types of player’s interaction with the game.

While gaming actions describe what a player does, *gaming tools* (Table 2) are the components that make actions possible, i.e. the components that the player manipulates or with which he or she interacts. They can also be the rules or characteristics of gameplay that define how actions can be taken in the game.

Gaming goals (Table 3) describe, in general terms, the types of goals and sub-goals typically found in games. Gaming goals complete the activity system

Gaming actions	
Category	Elements
Entity Manipulation	Capture, Collect, Create, Customize, Design, Destroy, Edit, Eliminate, Exchange, Generate, Manage resources, Manipulate gravity (physics), Match, Own, Plan / Strategy, Remove, Select, Tactical maneuver, Trade virtual items
Movement	Avoid, Collide, Move, Evade, Rotate, Shoot, Target, Teleport, Traverse, Visit
Time-related	Manipulate time, Start/ Stop time, Advance game period
Information	Ask questions, Answer questions / trivia, Obtain help, See performance evaluation, Watch / Listen to / Read information, Watch / Listen to / Read story

Table 1: Gaming actions

triangle (see Section 2) at this level of analysis: every gaming action is performed using one or more gaming tools, to achieve at least one gaming goal.

Gaming tools	
Category	Elements
Objects	2D/3D space, Avatars, Cards, Gifts, Goods, Grids, Information, Modifiers, Non-playing characters (NPC), Tiles, Tokens, Virtual money
Attributes	Lives, Position in space, Roles, Secrets, Virtual skills
Time	Chronometer, Time pressure
Feedback	Achievements, Leaderboards, Penalties, Performance meters, Performance record, Points, Progress bars, Rewards, Status levels
Help	Advice and assistance, Guide character, Checklists/ Task lists, Tips, Tutorial, Warning messages
Chance / Randomness	Dice, Lottery, Random appearances, Randomizers
Narrative (aesthetics)	Cut scenes, Role play, Story (text)
Rules	Complete information, Incomplete information, Competition, Game modes, Game master / referee, Multiplayer, Zero-sum / Non-zero-sum
Segmentation of gameplay	Alternating turns, Challenges, Checkpoints, Game Period, Infinite gameplay, Levels, Meta-game, Puzzles, Quest / Problem, Time
Goal metrics	Achievement, Performance record, Score, Success level, Time
Score	Video Game Score, Cash Score, Social Network Score, Composite Metrics, Experience Points, Redeemable Points, Karma Points

Table 2: Gaming tools

Gaming goals	
Category	Elements
Score	Maximize performance, Maximize score
Tasks	Collect resources, Collect information, Solve puzzle
Narrative	Complete quest, Complete side quests, Form/discover goal, Get acquainted with story, Reach narrative end
Competition	Be the first to reach the end, Be the last player standing
Other goals	Configure game, Learn to use interface, Perform task within allotted time, Reach resources end

Table 3: Gaming goals

6.2. Learning components

The list of learning components is mostly based on Bloom’s Updated Taxonomy (Anderson et al., 2001), which is arguably the most commonly used framework to describe learning goals. To complement Bloom’s Updated Taxonomy, two other taxonomies are used: Kolb’s Experiential Learning Cycle (Kolb, 1984) and Fink’s Taxonomy of Significant Learning (Fink, 2003). Kolb’s Cycle incorporates a constructivist perspective, while Fink’s Taxonomy includes learning goals that are less curricular and more focused on transferrable skills such as critical thinking, creativity, problem solving, etc.

Learning actions (Table 4) are the actions that the player/learner performs in the game, while *learning tools* (Table 5) are the in-game artifacts that support one or more actions. To generate the list of actions and tools, we combined LM-GM’s original learning mechanics with a list of illustrative action verbs based on Bloom’s Updated Taxonomy (Almerico and Baker, 2004; Illinois Central College, 2011).

The *learning goals* list (Table 6) is a direct reproduction of Bloom’s Updated Taxonomy (cognitive, affective and psychomotor domains), Kolb’s Experiential Learning Cycle, and Fink’s Taxonomy.

Learning actions	
Category	Elements
Remembering	Define, Describe, Draw, Find, Identify, Imitate, Label, List, Locate, Match, Memorize, Name, Observe, Read, Recall, Recite, Recognize, Relate, Reproduce, Select, State, Write, Tell
Understanding	Compare, Convert, Demonstrate, Describe, Discuss, Distinguish, Explain, Explore, Find more information about, Generalize, Interpret, Objectify, Outline, Paraphrase, Predict, Put into own words, Relate, Restate, Summarize, Translate, Visualize
Applying	Apply, Calculate, Change, Choose, Classify, Complete goal, Complete, Construct, Examine, Experiment, Illustrate, Interpret, Make, Manipulate, Modify, Perform action/task, Produce, Put into practice, Put together, Show, Solve, Translate, Use
Analyzing	Advertise, Analyze, Categorize, Compare, Contrast, Deduce, Differentiate, Discover, Distinguish, Examine, Explain, Identify, Investigate, Separate, Subdivide, Take apart
Evaluating	Argue, Assess, Choose, Critique, Debate, Decide, Defend, Determine, Discuss, Estimate, Evaluate, Judge, Justify, Prioritize, Rate, Recommend, Review, Select, Value, Verify, Weigh
Creating	Add to, Build model, Combine, Compose, Construct, Create, Design, Devise, Forecast, Form goal, Formulate, Hypothesize, Imagine, Invent, Originate, Plan, Predict, Propose

Table 4: Learning actions, based on Almerico and Baker (2004) and Illinois Central College (2011)

Learning tools

Category	Elements
Dramatizing	Dramas, Dramatizations
Graphical information	Art, Cartoons, Diagrams, Displays, Graphed information, Graphics, Graphs, Illustrations
Interaction	Court trials, Debates, Demonstrations, Experiments, Group discussions, Questionnaires, Simulator, Speculations, Surveys, Tests
Multimedia	Animation, Films, Media presentations, Recordings, Songs, Speech, Television programs, Videos
Problem-solving	Challenge, Problems, Puzzles
Textual information	Analogies, Arguments, Bulletin boards, Classifications, Conclusions, Definitions, Editorials, Forecasts, Information, Magazine articles, Models, Newspapers, Organizations, Outlines, Poems, Posters, Recommendations, Reports, Routines, Rules, Standards, Story, Student diary, Summaries, Task list/ checklist, Tasks, Textbooks, Texts, Tips
Other	Creations, Events, Inventions, Sculptures, Self-evaluations, Systems, Values

Table 5: Learning tools, based on Almerico and Baker (2004) and Illinois Central College (2011)

Learning goals	
Category	Elements
Bloom's Taxonomy – Cognitive domain	Remembering, Understanding, Analyzing, Applying, Evaluating, Creating
Bloom's Taxonomy – Affective domain	Receiving phenomena, Responding to phenomena, Valuing, Organization, Internalizing values
Bloom's Taxonomy – Psychomotor domain	Perception (awareness), Set, Guided response, Mechanism (basic proficiency), Complex overt response, Adaptation, Origination
Kolb's experiential learning cycle	Concrete experience, Active experimentation, Reflective observation, Abstract conceptualization
Fink's Taxonomy	Foundational knowledge, Application, Integration, Human dimension, Caring, Learning how to learn

Table 6: Learning goals

6.3. Instructional components

The instructional activity has a different subject: the person(s) teaching something using the serious game. There is a conceptual overlap between the instructional activity and the learning activity, as they are complementary ways of analyzing the same process. The instructional activity depicts how instructors and/or game designers act to facilitate the learning process, particularly by providing adequate conditions for it to occur.

The taxonomy does not distinguish between intrinsic and extrinsic instructional components, since the distinction between the two depends solely on where the components are used: if inside the game, they correspond to intrinsic instruction; if outside of it, they are related to extrinsic instruction.

Just as in the case of learning actions and tools, *instructional actions* (Table 7) are the actions that the game and/or the instructor perform during the course of the game with the objective of stimulating *learning actions* and facilitating *learning goals*.

Instructional actions	
Category	Elements
-	Demonstrate, Present material, Present problem, Present quiz, Qualitatively assess performance, Quantitatively assess performance, Repetition, Review lesson, Reward good performance, Sanction bad performance, Scaffold, Show similar problems, Stress importance, Suggest improvements, Support recovery from errors, Tell story

Table 7: Instructional actions

Instructional tools (Table 8) are components present in the game that support *instructional actions*, providing help and feedback to learners and assessing their performance. There may be overlaps between *learning tools* and *instructional tools*.

Instructional tools	
Category	Elements
-	Challenge, Checklists, Deadlines, Discussion, Help text, Limited set of choices, Multiple chances, Penalties, Performance measures, Practice tests, Questions & answers, Rewards, Simulators, Story, Tips / assistance, Warning messages

Table 8: Instructional tools

Each *instructional action* has one or more *instructional goals* (Table 9). Two theories widely employed in instructional design were used as reference to identify the goals of *instructional actions*: Gagné's Nine Events of Instruction (Gagné, 1985) and Keller's ARCS Model of Motivational Design (Keller,

1987). The events of instruction are external events that the instructor can elicit, in sequence, to provide an adequate environment for effective learning. The ARCS model, on the other hand, lists four steps that can promote and sustain motivation during the learning process.

Instructional goals	
Category	Elements
Gagné’s Nine Events of Instruction	Gain attention, Inform learner of objective, Stimulate recall of prior learning, Present the stimulus, Provide learning guidance, Elicit performance, Provide feedback, Assess performance, Enhance retention and transfer
ARCS Model of Motivational Design	Attention, Relevance, Confidence, Satisfaction

Table 9: Instructional goals

7. Application of ATMSG

7.1. Description

In this section, we propose a four-step approach that progressively guides the user in applying the ATMSG model to the analysis of serious games to gain a better understanding on how learning takes place in the game. These steps take the user from a high-level understanding of the activities to the concrete components that implement those activities. The user identifies game components with the help of the taxonomy of serious game components (described in Section 6).

Figure 6 outlines the four steps of the approach. Each step is described below.

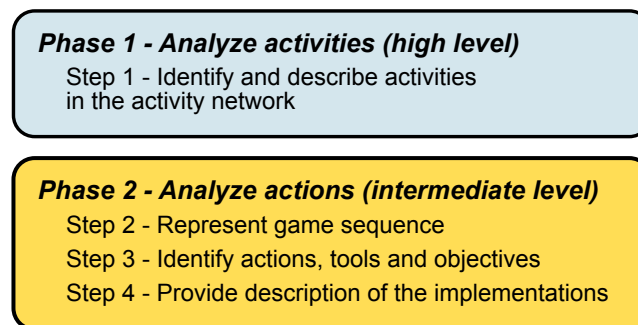


Figure 6: The four-step approach for applying the Activity Theory-based Model of Serious Games (ATMSG) to the analysis of educational serious games

Step 1: Describe the activities

In the first step, the user describes the main activities involved in the activity system and identifies their subjects and corresponding motives (Table 10). Each description shifts the user’s understanding of the game and highlights the main aspects of each activity, encouraging the user to observe the game from different but complementary aspects.

Activity	Subject	Description
Gaming	Who is the player?	Why is the subject playing? What are the general objectives of the game?
Learning	Who is the learner?	Why is the subject engaging with the game? What are the learning objectives of the game?
Intrinsic instruction	Who designed/produced the game?	Why was the game produced? How is the game trying to convey its learning contents?
Extrinsic instruction	Who is using the game to teach something?	Why is the subject using the game? How is the game used to teach something? Are there any other tools used in conjunction with the game to achieve the learning objectives?

Table 10: Guiding questions to describe activities

Filling in the fields for the extrinsic instructional activity is not necessary when the analysis is not related to a specific usage context.

It is not always possible to describe precisely what are the motives driving the activities, as motives are highly personal and variable. In these cases, the motives have to be presumed by the person performing the analysis. Nevertheless, even mere presumptions are valuable, as they can help detect inconsistencies and contradictions between the high-level motives driving the activities and the concrete actions chosen to implement that activity, indicating possible problematic points for the player’s engagement with the game.

Step 2: Represent the game sequence

To help in the identification of the components of the serious game, the user produces a diagram that represents the game sequence in a rough timeline. The purpose of this diagram is to establish a reference point to uncover how the components of the activity system, which will be identified in Step 3, are connected throughout the game. It also facilitates a visual comparison between multiple games, even if they are of completely different genres. The game sequence visually describes the overall structure of the game, marking points in which choices or evaluations of the game state are made and loops that indicate the repetition of similar arrangements in the game.

The game sequence representation follows the Unified Modeling Language

(UML) activity diagrams notation, which uses shapes connected by arrows to represent the flow of the activities (see Figure 7). UML was chosen for its status as de facto standard in the software engineering field (Kim et al., 2003).

Step 3: Identify actions, tools and goals

In this step, the user proceeds to identify components related to each node of the game sequence. At this level of the analysis, each event in the game is decomposed into its actions, tools and goals. Together, the components answer, for each step of the game, the question: “what is the subject doing, how, and why?”

The user chooses the relevant component directly from the taxonomy of serious game components. The graphical representation of these relationships consists of a layered table in which the components are placed, matching vertically the node of the game sequence to which they are related (see Figure 7 for an example). For each activity involved (gaming, learning, intrinsic instruction and the optional extrinsic instruction), there are three layers to be filled (actions, tools and goals), totaling nine (or twelve, if considering the extrinsic instruction) layers.

Table 11 presents guiding questions that can help the user when mapping serious game components.

Not all nodes of the game sequence will have actions of all the activities happening at the same time. Similarly, more than one action can happen at the same time in the same activity. Some components of the taxonomy may be relevant to the game as a whole (e.g. certain rules of play, whether the game is a 3D space, etc.), and should be indicated in the beginning of the table, before the start of the game sequence representation.

The result of this step is a blueprint of the game structure that reflects the essential form of the serious game components (Figure 7).

	Gaming activity	Learning activity	Intrinsic instruction activity	Extrinsic instruction activity
Actions	How does the game unfold? Which actions does the subject perform in the game?	What tasks does the subject do in the game that are directed towards the learning goal?	What happens in the game that supports the learner to achieve the learning goals (assessment, feedback)?	What happens, during the game but outside of it, that supports the learner to achieve the learning goals?
Tools	Which elements are involved/used in the gaming actions?	Which elements are involved/used in the learning actions?	Which elements are involved/used in the game to support the instructional actions?	Which elements are involved/used, outside the game, to support the instructional actions?
Goals	What does the subject have to achieve in the game at this point?	Which knowledge or skills the learner is expected to acquire with the learning actions?	What are the instructional goals of the game at this point?	What are the instructional goals driving the actions described above?

Table 11: Questions to guide the identification of the actions, tools and goals

Step 4: Description of the implementation

In this step, the user groups each set of actions, tools and goals that are from the same type of activity and that are related to the same node of the game sequence. For each of those blocks, the user provides a more complete description of their implementation, explaining what is being done at that point in the game, using which tools, and with which purpose. In this description, the user can complement the description of the component with more specific details of its implementation (e.g. how a score is calculated, or the characteristics of a non-player character) and explain how the usage of such components and characteristics support the achievement of the entertainment and/or pedagogical goals of the game. This is done separately for each type of activity (Table 12).

When combined, the four steps described above provide a comprehensive view of the structure of the game, from its high-level purposes and general characteristics, to its concrete implementation.

7.2. ATMSG for serious game design

The ATMSG model can furthermore be used as a tool to support the serious game design process. In this case, Phase 1 of the application guide remains the same, as it focuses on high-level characteristics of the serious game that should be defined in the very beginning of the project. The difference lies in Phase 2, which should be applied in conjunction with prototyping techniques, preferably, but not limited to, low-fidelity ones (sketches, storyboards, game diagrams, etc.).

Starting from the description of the activities, the designer produces a first version of the game prototype, using his or her preferred method. This prototype is analyzed according to steps 2–4 described in Subsection 7.1. The resulting evaluation provides insights on the level of integration of the gaming and learning components, shedding light on possible weak points in the design. The designer adjusts the prototype accordingly, and subsequently repeats the steps, until a satisfactory structure has been achieved.

7.3. Example analysis

This section presents an ATMSG analysis of *DragonBox Algebra 5+* (We-WantToKnow, 2012), a critically acclaimed and commercially successful videogame for teaching algebra concepts to young children (Liu, 2012).

The analysis considers a child playing on his or her own, outside of any classroom activities and without the help of a parent, thus it includes only the intrinsic instructional activity.

Table 12 shows the descriptions of the activities of the game (Step 1). Note that these descriptions are related to the same event (the child playing the *DragonBox* game), but from three different standpoints (e.g. the fun aspect for the child; the learning aspect, also for the child; and the game’s point of view).

Activity	Subject	Description
Gaming	Children aged 5-12	The objective of the game is feed the dragon and watch it grow. To pass each level, the player must solve a series of puzzles, manipulating tiles until the DragonBox is alone in one side of the game board. Graphics, music and rewards follow the same general style of apps and games typically targeted at the same age group, keeping it familiar and fun.
Learning	Children aged 5-12	The puzzles are in fact algebraic equations that must be solved for an unknown variable, represented by the DragonBox. Graphical icons are progressively replaced by numbers and variables. Typically, there is no conscious motivation for the learning activity.
Intrinsic instruction	WeWantTo-Know	The game aims to introduce basic concepts of algebra in a fun way. It tries to remove the negativity surrounding the topic by making it as simple as possible to understand.

Table 12: Activities description of *DragonBox Algebra 5+*

Figure 7 represents the game sequence (Step 2) with the related game components depicted in layers (Step 3). The game sequence visually describes the overall structure of the game, which in this case is a repetition of the sequence “Interface tip”, “Puzzle” and “Rewards”, and constant evaluations about the state of the game (“is this a new skill to the player?”, “are there more puzzles in this chapter?”). The game is split in chapters, but the chapters do not differ in their structure – they only mark the progression through the topics. Vertically aligned to the nodes in the game sequence are the layers of serious games components. Only nodes 3, 4 and 5 contain components in the layers related to the learning and instructional activities, while nodes 1 and 2 are related to customization, learning the interface and getting the player involved in the game. This allows us to identify where the core of the learning experience is and which components characterize it (e.g. the tips, the challenges, the rewards, the scaffolding of challenges, the ability to recover from errors, etc.).

There is a clear overlap between the motivations driving the gaming and the learning activities, to the point that the learner typically will not be consciously aware of the learning goals (see Table 12). For the target audience, this is likely to be a positive characteristic to promote engagement. In addition, the designers of *Dragonbox* tried to make the gaming motives compelling enough to its audience, by using appealing and familiar graphics, music and rewards. Furthermore, the main gaming goals (“solve puzzles”, “maximize performance”) are directly related to the gaming motive (“feeding the dragon to watch it grow”), indicating that the player will be engaged in the concrete actions performed in the game so that the driving motive is fulfilled.

Table 13 provides more details on the implementation of the gaming components (Step 4). For example, in Figure 7 it is shown graphically that node 4 (“Puzzle”) has the following learning components: the actions “Repetition”, “Imitating”, “Experimenting”, the tool “Challenge” and the goal “Remembering”. Conversely, in Table 13, in the corresponding cell (i.e. in the “Puzzle” row, “Learning” column), we can read a more complete description of how these components are connected.

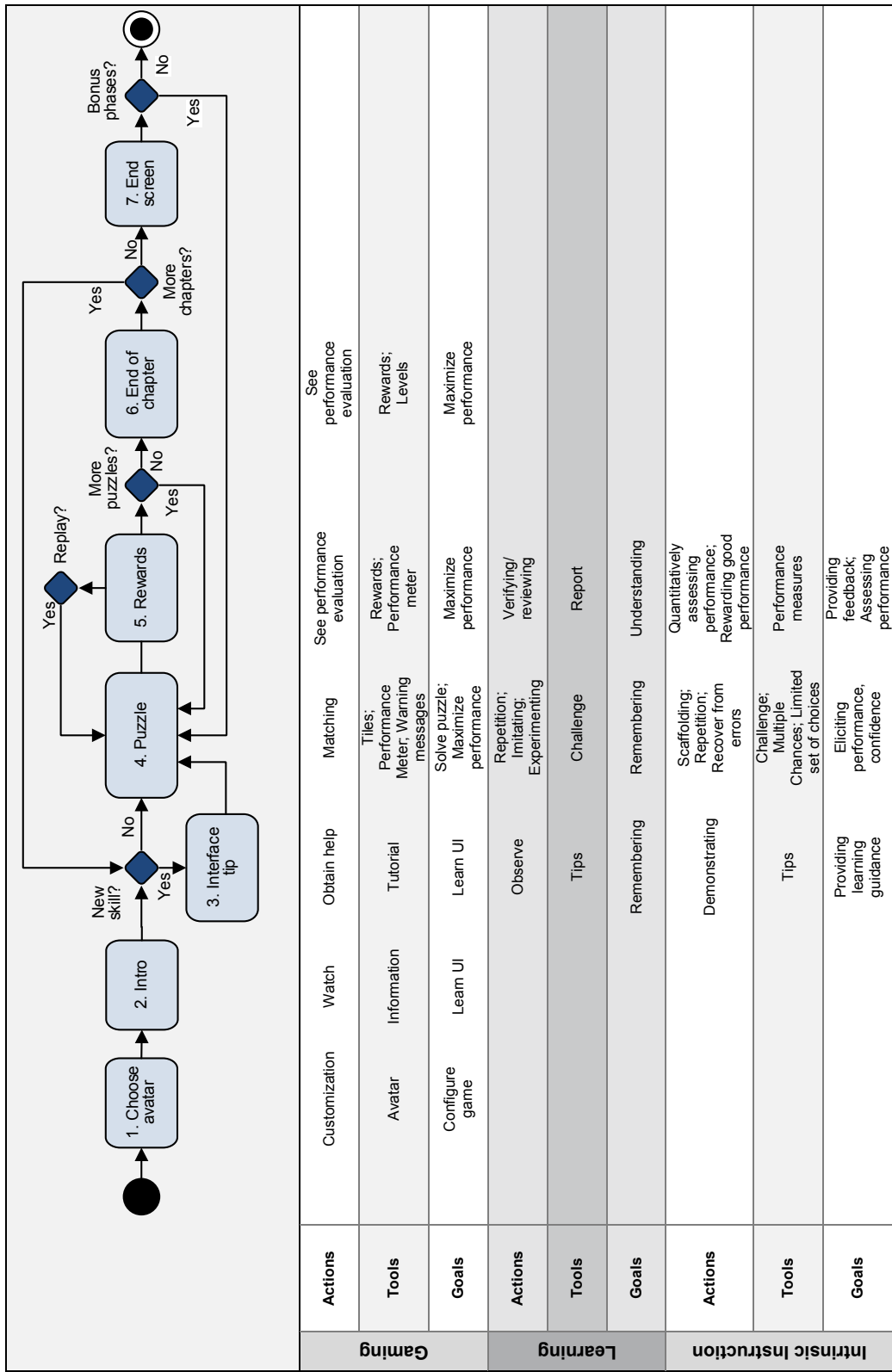


Figure 7: Game sequence and serious games components of *DragonBox Algebra 5+*

Game sequence node	Gaming	Learning	Intrinsic Instruction
1. Choose avatar	The player chooses a character as his or her avatar. The avatar is not used anywhere else in the game.	-	-
2. Introduction	A short animation explains the basic objectives and rules of the game.	-	-
3. Interface tip	If a new skill (“power”) is needed to solve the puzzle, the game shows an animation explaining the allowed movements.	The game conveys the rules of algebra by demonstrating the allowed movements.	No verbose explanations are given. Simple tips provide the guidance the player needs to solve the puzzles.
4. Puzzle	The player has to move and combine tiles to isolate the DragonBox in one side, using as few movements as possible. The interface forces the player to follow the rules. The player can play the same puzzle as many times as she wants.	Puzzle after puzzle, the player has to repeat the same patterns until they become automatic. Experimenting with the rules is encouraged, as the interface forces the user to balance the equations correctly.	Puzzle complexity increases very gradually. Skills are accumulated over several levels. The interface prevents the player from making mistakes, which avoids frustration and increases the player’s confidence.
5. Rewards	After completing the puzzle, the player earns stars for each possible achievement. Extra points are given when the puzzle is solved in fewer movements and when no extra elements are left in the board.	It is not possible to give wrong answers, but the player can earn extra points for eliminating extra pieces and for using fewer movements. The player can repeat the level to achieve a better score with no penalties.	Assessment of player’s performance gives feedback on which rules were not completely followed and elicits the player to try again.
6. End of chapter	A screen showing the full-grown dragon marks the end of the level. A player can share his or her achievements in different social networks.	-	-
7. End screen	When all levels have been completed, the player is invited to play the bonus stages, which feature algebraic equations in proper mathematical notation.	-	-

Table 13: Description of the implementations of *DragonBox Algebra 5+*

8. Evaluation

We performed three preliminary evaluation studies of ATMSG in which we investigated the users’ perception of the usability and usefulness of the model. The goal was to obtain early user feedback in order to address issues, particularly on usability, before proceeding with more extensive user testing. The first study evaluated ATMSG on its own, while the subsequent ones compared it with the LM-GM model (Arnab et al., 2014).

The data set supporting the results of this evaluation is available in the DANS repository (Carvalho, 2015a). A complete report of the studies and replication files are also available (Carvalho, 2015b).

8.1. Participants

We recruited, in total, 32 participants aged 19–44 ($M = 23.34$, $SD = 4.78$). Participants of Study 1 ($N = 13$) were students of a Masters-level course on Entrepreneurship using serious games in the University of Genoa, Italy. Participants of Study 2 ($N = 15$) were industrial engineering students of an undergraduate course at the University of Bremen, Germany. For Study 3, we recruited, via specialized mailing lists and social media, a group of self-identified serious games experts ($N = 4$), who were offered a small monetary compensation for their time.

Table 14 lists the participants’ self-reported level of familiarity with digital games and with serious games in a 1–5 scale.

Familiarity	With games	With SGs
None	.	.
Played once or twice	.	17
Played a few times	14	10
Plays now and then	3	1
Plays frequently	15	4
Sum	32	32

Table 14: Number of participants by familiarity with games and with serious games

8.2. Set up

The general structure of the three studies was the same, with the difference that in Study 1 the participants evaluated only the ATMSG model, while in the subsequent studies participants evaluated both ATMSG and LM-GM.

- *Study 1*: participants used the ATMSG model to analyze the game *Marketplace Live*, a business simulation serious game, which they had been playing for a period of 8 weeks as part of the normal activities of the course.
- *Study 2*: participants evaluated both ATMSG and LM-GM over the course of two weeks. The games used in the evaluations were *Playing History: Vikings*, an adventure game to teach history for children, and *Senior PM*

Game, a simple simulation game to teach project management to university students. Participants were split into two groups to alternate which model was used first. Three participants did not participate in the second day of the evaluation. Their responses were discarded in the comparisons between the two models (since they did not have a matching sample), but were kept to compute average usability scores.

- *Study 3*: participants were asked to evaluate one single game (*Senior PM Game*) using both ATMSG and LM-GM. The order in which the models were presented to each participant was assigned at random. The study was conducted using an online survey tool.

In all cases, participants first received an explanation on the model. Subsequently, they were asked to apply the model to analyze a serious game, using either paper or digital templates. They were then asked if the model had contributed to any change in their perception of the game and if they had any suggestions to improve the model. In the cases where participants evaluated both ATMSG and LM-GM, we also asked them to compare the models.

We inquired the participants about their experience with the model using an adapted version of the System Usability Scale (SUS) questionnaire (Brooke, 1996). SUS is a simple, ten-item attitude Likert scale giving a global view of subjective assessments of usability, which yields a single usability score on a scale of 0–100.

8.3. Qualitative data processing

In addition to the usability scores, we also collected qualitative data on the participants' experiences with the models: the open-ended questions on how the model affected their perception of the game, the comparisons between ATMSG and LM-GM, the game diagrams and tables (Figures 8 and 9) and the researcher's written observations on the days of the studies.

To process the participants' comments, we first discarded empty answers, and answers in which the participant misunderstood the question (e.g. they feedback about the game itself and not about the model). We were left with feedback from 25 participants. These answers were coded to identify general statements about both models. Each answer could have one or more general statements. These general statements were grouped, and the results are presented in the next subsection.

8.4. Results

We could identify usability issues with the ATMSG model, both in the qualitative data and in the scores obtained with the SUS questionnaire. Results indicate that the ATMSG model has a steep learning curve: six participants (19%) mentioned that the application of the ATMSG model could be simplified, and, in four cases (12%), the participants stated that they needed detailed instruction and examples to be able to perform the analysis. This feedback was consistent with the average usability score of the ATMSG model obtained from the SUS questionnaires, which was 58.83 ($N = 30$, $SD = 17.5$), in a scale of 0–100.

Nevertheless, in general, participants considered that using either model helped them understand better the characteristics of the game. LM-GM was

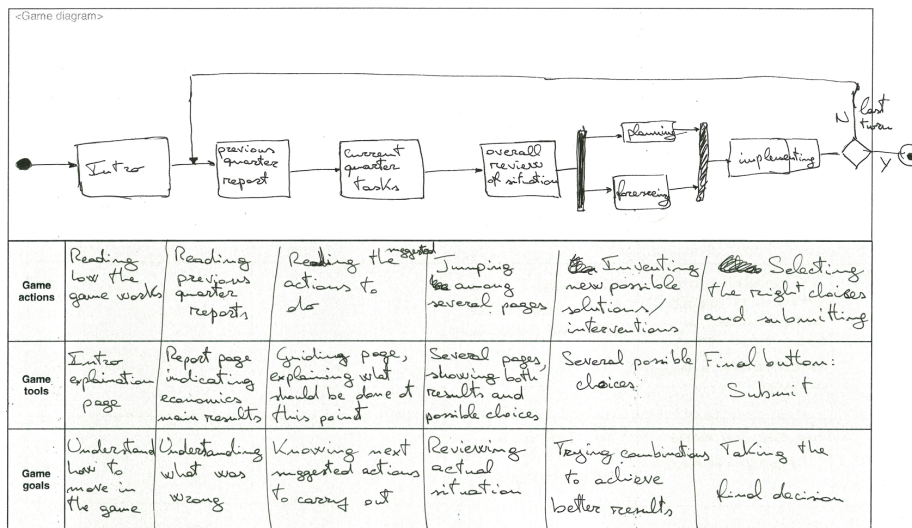


Figure 8: ATMSG diagram layers filled as expected, with proper vertical alignments

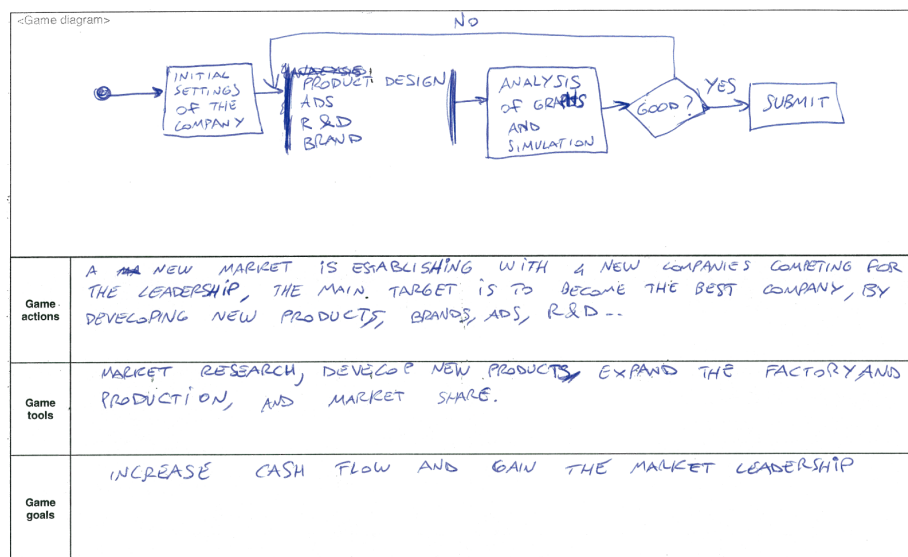


Figure 9: ATMSG diagram layers filled in an unexpected way

Learning actions		Learning tools	Learning goals				
Completing goal	Memorizing		Bloom's Taxonomy – Cognitive domain	Bloom's Taxonomy – Affective domain	Bloom's Taxonomy – Psychomotor domain	Kolb's experiential learning cycle	Fink's Taxonomy
Discovering	Model building	Animation	Remembering	Receiving phenomena	Perception (awareness)	Concrete experience	Foundational Knowledge
Discriminating	Objectifying	Challenge	Understanding	Responding to phenomena	Set	Active experimentation	Application
Discussion	Observing	Graphics	Analyzing	Valuing	Guided response	Reflective observation	Integration
Experimentating	Participating	Information	Applying	Organization	Mechanism (basic proficiency)	Abstract conceptualization	Human dimension
Exploring	Participating in conversation	Report	Evaluating	Internalizing values	Complex Overt Response		Caring
Forming hypothesis	Performing action/ task	Simulator	Creating		Adaptation		Learning how to learn
Forming goal	Planning	Story			Origination		
Generalizing	Puzzlement	Student diary					
Identifying	Reading	Task list/ Checklist					
Imitating	Repetition	Tasks					
Listening	Selecting/ Choosing	Tests					
Locating	Verifying/ Reviewing	Text					
		Video					

Figure 10: Some participants preferred to circle items in the taxonomy reference tables

well evaluated by a large number of participants: among the 18 participants who used LM-GM, 13 (72%) mentioned that LM-GM was helpful for them. Conversely, 14 participants (47% out of 30) said the same about the ATMSG model.

To make direct comparisons between ATMSG and LM-GM, we only considered data from participants who used both models, discarding three responses that did not have a matching sample. This gave us a sample of 32 questionnaires from 16 participants. Thirteen participants (81%) stated that ATMSG is more complete and detailed than LM-GM, and two participants (12%) considered that the ATMSG game diagram is easier to draw. LM-GM, on the other hand, was considered simpler or easier to grasp by nine participants (56%), seven of them non-gamers. One participant commented that maybe they would have been more comfortable with ATMSG if they had been exposed to LM-GM first.

The difference in perception between the two models noted in the qualitative data was also apparent in the SUS usability scores, although the sample size is small to draw definitive conclusions. For the non-gamers group ($N = 8$), the average usability score for ATMSG was 42.8, while for LM-GM it was 57.5. For the gamers group ($N = 8$), the average usability score for ATMSG was 74.4 and for LM-GM it was 65.6. A mixed between-within subjects ANOVA was conducted to compare the usability scores given by participants for each of the two models and to identify if the scores varied with familiarity with games. There was a significant effect of the different levels of familiarity in the usability scores, $F(1, 14) = 14.87, p = .002, \eta_G^2 = 0.32$, but no effect due to the model used, $F(1, 14) = 0.37, p = 0.55, \eta_G^2 = 0.007$.

We also considered in the qualitative analysis our own observations of the participants' behaviour and the documents they delivered at the end of the studies. We noticed that some participants using ATMSG relied heavily on the taxonomy to perform their analyses, particularly in making the distinction between items from gaming and learning activities. Furthermore, some participants did not produce the game diagram with the components in a vertically matching position (Figure 9), simply preferring to circle the relevant items in the taxonomy reference tables (Figure 10). Finally, in many instances during the studies, participants asked for clarifications on the entries of the taxonomy of serious games components, being unsure of the meaning of certain terms.

9. Discussion

The ATMSG model has the objective of supporting the analysis and design of serious games for two user groups: experts in serious games, and non-experts who are involved in serious games related projects, such as teachers and application domain experts (e.g. trainers, advertisers, managers, etc.). Our preliminary evaluation indicates that the structured analysis supported by ATMSG is helpful to users in understanding in depth the roles of each piece in each action that happens inside the game. The decomposition of components is more detailed than that provided by the LM-GM model, which only specifies two main sets of components, namely “game mechanics” and “learning mechanics”, with no other distinctions on the nature of these components. For example, an LM-GM analysis of the game DragonBox Algebra 5+ is able to identify that the component *tutorial* is present as a “learning mechanism”. An ATMSG analysis of the same game, conversely, allows the user to be more precise and describe that the player’s action of *observing* the *tips* exposes him to the mathematical concepts that have to be *remembered*. Those same *tips* are used by the game when *demonstrating* allowed moves, thus *providing learning guidance* to the player. Furthermore, the ATMSG model also provides a more extensive list of components (almost 400 items classified in 36 categories, versus LM-GM’s list of 38 game mechanics and 31 learning mechanics), which also contributes to the precision of the identification of components in the game.

The increased level of detail provided by ATMSG, nevertheless, results in a steeper learning curve, particularly to non-expert users or to those who are less acquainted with digital games. To this group of users, LM-GM’s simpler analysis was already enough to provide useful insights on the game structure and educational purposes. This suggests that LM-GM provides a good understanding of the game when only a general idea of the game’s learning mechanisms is needed, such as when several different games need to be quickly evaluated by non-serious games experts, e.g. teachers selecting a game for a class. ATMSG, conversely, is more suitable for situations in which a more profound understanding of the components is necessary, for example when adapting games for use in specific learning settings, when detailing the analysis to identify and catalog learning patterns or when evaluating game prototypes during the design process — in other words, when a thorough understanding of the characteristics of the game is needed.

The evaluation study highlighted a few usability problems of the application of the ATMSG model. Some of these issues, such as the need to simplify the ATMSG model and to clarify the tables, have already been addressed. Nevertheless, a few other points still need improvement, such as the fact that the taxonomy entries should be expanded to include descriptions and examples as well. A complementary textual description may provide details on typical characteristics of the item, while examples would be useful to illustrate the actual usage of the item in a game. Additionally, the application of the taxonomy to a wider variety of serious game genres could favor the expansion or refinement of the entries by the incorporating eventually missing components and removing those that are not relevant. Finally, we identified the need to provide a more appropriate medium for the application of ATMSG, such as a computer application or a set of cards or similar tools that can be easily moved around while performing the analysis.

Further evaluation studies will be needed, with a few modifications. Firstly, this study focused on the analysis of existing games only, but we would also like to verify the applicability of the model in the conceptual design of serious games. In addition, in the current study, we employed a usability scale in our measurements, since the purpose of the evaluation was to iteratively improve the tool itself. The SUS scale measured how easy or difficult it was to use and understand the model, but it did not allow us to investigate the model's usefulness. In subsequent studies, we intend to use scales that measure user satisfaction instead, in addition to collecting open-ended comments and analyzing the quality of the ATMSG analyses produced by the users. Furthermore, considering that ATMSG seems to be more useful to expert users, the next studies should target specifically this user group. Finally, to mitigate problems with low motivation of the participants, future evaluations should be performed preferably in contexts in which there is a real need for an analysis tool.

10. Conclusion and future work

The ATMSG model provides a comprehensive way to investigate, in detail, how a serious game is structured, using activity theory as the theoretical background. Compared to other models, methodologies and frameworks currently available, ATMSG offers a more precise model for the analysis of the educational and gaming aspects of a game, allowing the user to perform a more exhaustive decomposition of components as the game unfolds, and to link these components to the overall learning objectives. Users with familiarity with digital games were more comfortable with the model. For non-gamers, ATMSG seems to have a somewhat steep learning curve, although this user group still recognizes benefits from applying the model in the analysis of serious games.

ATMSG provides a more detailed analysis of serious games but is also more complex. Consequently, the application of the method requires more time and a better understanding of game components. Thus, if only a general idea of pedagogical aspects of a game is needed, other tools (e.g. Four-Dimensional Framework, RETAIN model, LM-GM) are most likely more appropriate. LM-GM, which was the other model evaluated in this work, also provides users with valuable insights on the structure of a serious game, but the description of the inner components of the serious games are not as detailed as ATMSG's, consequently this model gives less detailed insights to the game structure.

While considering a variety of gaming and learning factors, the ATMSG model does not contemplate the underlying social structures that mediate the relationship of the subject and the object with the community. This limitation reflects the features offered by the great majority of state of the art serious games, but should be addressed in the near future. In particular, the model should incorporate the analysis of collaboration and cooperation aspects in a serious game.

Future work on the ATMSG model also includes the development of a software to facilitate the application of the model, offering a more adequate and usable interface to generate the diagrams, choose components and put them in the appropriate place in the game representation. Such a tool could support non-expert users in applying ATMSG, helping minimize the challenges that we identified in the evaluation of the model. Furthermore, the analyses produced by the tool will be stored in an interchangeable format, which will allow the

analyses to be archived in repositories for serious game studies, such as the Serious Games Studies Database (Serious Games Society, 2013), and used as input material for cataloging game-based learning patterns.

Acknowledgements

This work has been partially funded by the EC, through the GALA EU Network of Excellence in Serious Games (FP7-ICT-2009-5-258169). This work was supported in part by the Erasmus Mundus Joint Doctorate in Interactive and Cognitive Environments, which is funded by the EACEA Agency of the European Commission under EMJD ICE FPA n 2010-0012.

References

- Adams, E. and Dormans, J. (2012). *Game mechanics: advanced game design*, New Riders.
- Almerico, G. M. and Baker, R. K. (2004). Bloom's taxonomy illustrative verbs: Developing a comprehensive list for educator use, *Florida Association of Teacher Educators Journal* **1**(4): 1–10.
- Amory, A. (2007). Game Object Model version II: a theoretical framework for educational game development, *Educational Technology Research and Development* **55**(1): 51–77.
- Anderson, L. W., Krathwohl, D. R. and Bloom, B. S. (2001). *A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives*, Longman.
- Arnab, S., Lim, T., Carvalho, M. B., Bellotti, F., de Freitas, S., Louchart, S., Suttie, N., Berta, R. and de Gloria, A. (2014). Mapping learning and game mechanics for serious games analysis, *British Journal of Educational Technology* .
- Bellotti, F., Berta, R. and De Gloria, A. (2010). Designing effective serious games: Opportunities and challenges for research, *International Journal of Emerging Technologies in Learning (iJET)* **5**(SI3): 22–35.
- Bellotti, F., Berta, R., De Gloria, A., D'Ursi, A. and Fiore, V. (2012). A serious game model for cultural heritage, *Journal on Computing and Cultural Heritage* **5**(4): 1–27.
- Bellotti, F., Berta, R., De Gloria, A. and Primavera, L. (2010). Supporting authors in the development of task-based learning in serious virtual worlds, *British Journal of Educational Technology* **41**(1): 86–107.
- Brooke, J. (1996). SUS – a quick and dirty usability scale, in P. W. Jordan, B. Thomas, B. A. Weerdmeester and A. L. McClelland (eds), *Usability evaluation in industry*, Taylor & Francis, London.
- Bura, S. (2006). A game grammar.
URL: <http://www.stephanebura.com/diagrams/>

- Carvalho, M. B. (2015a). Comparison of two models for serious games analysis.
URL: <http://persistent-identifier.nl/?identifier=urn:nbn:nl:ui:13-r5t6-mn>
- Carvalho, M. B. (2015b). SG Study Github repository.
URL: https://github.com/carvalhomb/sgmodels_study
- Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*, Harper and Row.
- De Freitas, S. and Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated?, *Computers & Education* **46**(3): 249–264.
- Devane, B. and Squire, K. D. (2012). Activity theory in the learning technologies, in D. H. Jonassen and S. M. Land (eds), *Theoretical foundations of learning environments*, Routledge, New York, chapter 10, pp. 242–267.
- Djaouti, D., Alvarez, J., Jessel, J.-P. and Methel, G. (2007). Towards a classification of video games, *Artificial and Ambient Intelligence convention (Artificial Societies for Ambient Intelligence) (AISB (ASAMi) 2007)*.
- Dormans, J. (2009). Machinations.
URL: <http://www.jorisdormans.nl/machinations/>
- Engeström, Y. (1987). *Learning by Expanding: An Activity-theoretical Approach to Developmental Research*, Orienta-Konsultit Oy.
- Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization, *Journal of Education and Work* **14**(1): 133–156.
- Erhel, S. and Jamet, E. (2013). Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness, *Computers & Education* **67**: 156–167.
- Fink, L. D. (2003). *Creating significant learning experiences: An integrated approach to designing college courses*, John Wiley & Sons.
- Gagné, R. (1985). *The Conditions of Learning and Theory of Instruction*, CBS College Publishing.
- Games Enhanced Learning (2010). Educational game design patterns.
URL: <http://amc.pori.tut.fi/educational-game-design-patterns/>
- Greitzer, F. L., Kuchar, O. A. and Huston, K. (2007). Cognitive science implications for enhancing training effectiveness in a serious gaming context, *Journal on Educational Resources in Computing* **7**(3): 2–es.
- Guillén-Nieto, V. and Aleson-Carbonell, M. (2012). Serious games and learning effectiveness: The case of It’s a Deal!, *Computers & Education* **58**(1): 435–448.
- Gunter, G. A., Kenny, R. F. and Vick, E. H. (2006). A case for a formal design paradigm for serious games, *The Journal of the International Digital Media and Arts Association* **3**(1): 93–105.

- Guy, E. S. (2005). *From rollout to appropriation: changing practices of development and use during a groupware project*, Phd thesis, University of Brighton.
- Hasan, H. (1999). Integrating IS and HCI using activity theory as a philosophical and theoretical basis, *Australasian Journal of Information Systems* **6**(2): 44–55.
- Hunicke, R., Leblanc, M. and Zubek, R. (2004). MDA: A formal approach to game design and game research, *Proceedings of the Challenges in Games AI Workshop, 19th National Conference of Artificial Intelligence*, San Jose, California, pp. 1–5.
- Illinois Central College (2011). Revised bloom’s taxonomy.
URL: http://www.icc.edu/innovation/PDFS/assessmentEvaluation/RevisedBloomsChart_bloomsverbsmatrix.pdf
- Islas Sedano, C. (2012). *Hypercontextualized games*, PhD thesis, University of Eastern Finland.
- Jonassen, D. H. and Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environments, *Educational Technology Research and Development* **47**(1): 61–79.
- Kaptelinin, V. (1996). *Context and consciousness: Activity theory and human-computer interaction*, The MIT Press Cambridge, MA, chapter Activity theory: Implications for human-computer interaction, pp. 103–116.
- Kaptelinin, V. and Nardi, B. A. (2006). *Acting with Technology: Activity Theory and Interaction Design*, The MIT Press, Cambridge, MA, USA.
- Kebritchi, M., Hirumi, A. and Bai, H. (2010). The effects of modern mathematics computer games on mathematics achievement and class motivation, *Computers & Education* **55**(2): 427–443.
- Keller, J. M. (1987). Development and use of the ARCS model of instructional design, *Journal of instructional development* **10**(3): 2–10.
- Kickmeier-Rust, M. D. and Albert, D. (2012). Educationally adaptive: Balancing serious games, *International Journal of Computer Science in Sport* **11**(1): 1–10.
- Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model, *The Internet and higher education* **8**(1): 13–24.
- Kiili, K. (2010). Call for learning-game design patterns, *Educational Games: Design, Learning, and Applications*, Nova Publishers.
- Kim, C.-H., Weston, R. H., Hodgson, A. and Lee, K.-H. (2003). The complementary use of IDEF and UML modelling approaches, *Computers in Industry* **50**(1): 35–56.
- Knight, J. F., Carley, S., Tregunna, B., Jarvis, S., Smithies, R., de Freitas, S., Dunwell, I. and Mackway-Jones, K. (2010). Serious gaming technology in major incident triage training: a pragmatic controlled trial., *Resuscitation* **81**(9): 1175–9.

- Kolb, D. A. (1984). The process of experiential learning, *Experiential learning: Experience as the source of learning and development*, Prentice-Hall, Englewood Cliffs, N.J., pp. 20–38.
- Koster, R. (2005). A grammar of gameplay. Game atoms: can games be diagrammed.
URL: <http://theoryoffun.com/grammar/gdc2005.htm>
- Koster, R. (2011). Social mechanics - the engines behind everything multiplayer.
URL: <http://www.raphkoster.com/gaming/gdco2010/socialmechanics.pdf>
- Kuutti, K. (1995). Activity theory as a potential framework for human-computer interaction research, in B. Nardi (ed.), *Context and Consciousness: Activity Theory and Human-computer Interaction*, MIT Press, Cambridge, pp. 17–44.
- Leont'ev, A. N. (1978). *Activity, consciousness and personality*, Prentice-Hall, Englewood Cliffs, NJ.
- Liu, J. H. (2012). DragonBox: Algebra beats Angry Birds.
URL: <http://archive.wired.com/geekdad/2012/06/dragonbox/>
- Marne, B., Wisdom, J., Huynh-Kim-Bang, B. and Labat, J.-M. (2012). The six facets of serious game design: a methodology enhanced by our design pattern library, *7th European Conference of Technology Enhanced Learning, EC-TEL 2012*, Vol. 7563, Springer Berlin Heidelberg, Saarbrücken, Germany, pp. 208–221.
- Marsh, T. (2006). Game development for experience through staying there, *Sandbox '06 Proceedings of the 2006 ACM SIGGRAPH symposium on Videogames*, Vol. 1, pp. 83–89.
- Marsh, T. (2010). Activity-based scenario design, development and assessment in serious games, *Gaming and cognition: Theories and practice from the learning sciences* pp. 213–225.
- Marsh, T. and Nardi, B. (2014). Spheres and lenses: Activity-based scenario/narrative approach for design and evaluation of entertainment through engagement, *Entertainment Computing-ICEC 2014*, Springer, pp. 42–51.
- Peachey, P. (2010). The application of ‘activity theory’ in the design of educational simulation games, *Design and Implementation of Educational Games: Theoretical and Practical Perspectives*, number 1988, IGI Gl, pp. 154–167.
- Schell, J. (2008). *The Art of Game Design: A book of lenses*, Vol. 54 of *Morgan Kaufmann*, Morgan Kaufmann.
- Serious Games Society (2013). SG knowledge management system.
URL: <http://studies.seriousgamesociety.org/>
- Sicart, M. (2008). Defining game mechanics, *Game Studies* 8(2).
URL: <http://gamestudies.org/0802/articles/sicart>

Van Staalduinen, J.-P. and de Freitas, S. (2011). A game-based learning framework: Linking game design and learning, *in* M. S. Khine (ed.), *Learning to play: exploring the future of education with video games*, Peter Lang, pp. 29–54.

WeWantToKnow (2012). DragonBox.

URL: <http://dragonboxapp.com>

Zagal, J. P., Mateas, M., Fernández-Vara, C., Hochhalter, B. and Lichti, N. (2005). Towards an ontological language for game analysis, *Proceedings of DiGRA 2005 Conference: Changing Views – Worlds in Play*.

Zaphiris, P., Wilson, S. and Ang, C. S. (2010). Computer games and sociocultural play: An activity theoretical perspective, *Games and Culture* **5**(4): 354–380.