Chapter 10
Strategies for Effective Digital Games Development and Implementation

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EXECUTIVE SUMMARY

Digital technologies have increased the pace of knowledge creation, sharing, and the way in which learning is being undertaken. This chapter considers how Serious Games (SGs) as a digital technology endeavours to support effective lifelong learning. Three fundamental characteristics of the SG ecosystem, namely, game mechanics, interoperability, and assessment, are considered here as strategic elements that impact upon how SGs are to support learning, how they affect the learning environ-

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ment, and ultimately, the SG development process. A prospective deconstruction of SGs into its pedagogical elements and its game mechanic nodes is presented to make aware the interoperability modus from which topical (domain) frameworks or architectures can be structured and assessed. To this end, the chapter explores the conceptual underpinnings through a case study on the eAdventure platform and argues that the key elements form the foundation for strategic development and implementation of SGs.

INTRODUCTION

The expansion of technology-enhanced learning coupled with the evolution of the "NET generation" has created new opportunities for immersive and engaging game-based experiences. Serious Games (SGs) represent an enhanced technological platform for complex skills learning (Westera, 2008). The caveat however is the dependence on technology to drive the learning process rather than the learner. Simply transcribing existing material and instructional method into a SG domain can be detrimental if careful consideration is not given to the designs and approaches for learning (Dror, 2008).

Considering the SG ecosystem is a useful way of thinking about structuring a strategy for its design. Serious games are by nature complex environments that need to function perpetually as an ecological unit. The credence to a SG's quality can be measured in terms of its fitness for purpose, utility and effectiveness. For educators SGs are increasingly viewed as an engaging technology to connect the learner. Evidence that learners seek experiential learning suggests learner-generated content to be a principle mechanism for SGs (Derryberry, 2008). That said, the use of games in formal curricula remains limited due in part to facilitator literacy, institutional infrastructure and pedagogical grounding (Zylka & Nutzinger, 2010) and time and monetary constraints of game development. Consequently, SG designers have to consider both the pedagogical practices that meet with the requirements for lifelong learning and one that demonstrates the game's learning objectives. It is in these contexts that this chapter discusses the game-based pedagogical relationships, conflicts and contradictions that exist. Along with exposing the difficulties associated with pedagogical conformance, the authors analyze interoperability as a critical factor to a successful SG development and deployment. This chapter summarizes the characteristics of the serious games field, with special focus on two key areas: (1) the challenges faced when trying to systematize educational game design methodologies that connect learning principles with game mechanics and (2) the need for interoperable ecosystems in which games (or game patterns) can be shared among practitioners to reduce costs and protect the investment. Finally, the chapter proposes a methodology for the creation of successful and interoperable game designs and proposes, as a case study, the employment of the eAdventure educational game design platform to follow the methodology.

BACKGROUND

SGs have evolved from simple, monolithic applications, to assemblies of finer-grained elements that create new value through the composition of high-level capabilities emerging from multiple pedagogical and technical dimensions. We begin with an overview to the SG ecosystem through to its acceptance.

An Overview of the Serious Games Ecosystem

From a pedagogical perspective, SGs are in essence game artefacts developed so as to support learning and should impact a learner on several levels. To begin it is necessary to understand how learners learn. Behaviourists surmise that learning is "the relative permanent change in behaviour brought about as a result of experience or practice." It is an internal event recognised only as learning when overt behaviour is displayed (Ingleby, 2010, pp. 62). Ritterfeld *et al.* (2009) identified Learning, Development and Change as essential dimensions for serious games. Recent developments in learning styles though have illustrated the need to engage student learning in a more psychosocial manner (Roberge, 2011; Boström, 2011). The emphasis here is on the environment used in teaching students how to think and learn (Zollinger, 2010,) and to stimulate individual abilities to learn (Boström, 2011). Then, to generate overt behaviour, learning mechanisms from theories such as contiguity, classical conditioning, and operant conditioning must be present in some manner within the SG's framework. This implies that, in terms of its mechanics and effects, a SG should not only be developed with a clear pedagogical focus, but should also aim to psychologically impact the player and elicit change.

From the standpoint of a game system, game mechanics are mainly used to describe how players interact with game rules and other formal properties such as goals, player actions and strategies and game states. Avedon and Sutton-Smith (1971) first identified a formal structure to games and fixed principles (i.e. courses of action, method of play, and procedure for action) that determined the conduct and behaviour of the game. Bjork and Holopainen (2005) regarded game mechanics as a pattern of rules designed in any part of the rule system of a game covering a unique set of interactions during the game, be it general or specific. Fullerton *et al.*

(2004) regarded game mechanics as rule bounded actions or methods of play, which create interactions and guide player behaviour. Hunicke *et al*. (2004) defined game mechanics at a computational system level and regarded them as actions, behaviours and control mechanisms afforded to the player within a game context. Cook (2006) related game mechanics to user actions and saw them as "rule-based systems/simulations that facilitate and encourage a user to explore and learn the properties of their possibility space through the use of feedback mechanisms". Rouse (2005) investigated game mechanics from a game design perspective and considered them to be part of the actual game design in the sense that "they describe what the players are able to do in the game world, how they do it, and how that leads to a compelling game experience." Jarvinen (2008) related game mechanics to the role they play in shaping the user's experience, guiding them to elicit a particular behaviour by constraining the space of possible plans to attain goals. Game mechanics are described with verbs to form rule sets that prescribe a causal relationship between game elements and their consequence to particular game states.

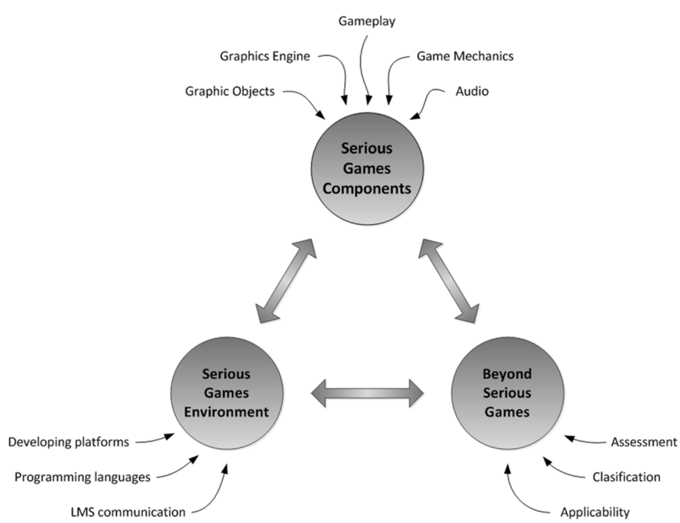
The plethora of literature has revealed that there are no concrete accepted definitions of game mechanics. Sicart (2008) concludes succinctly that game mechanics are "Something that connect player's actions with the purpose of the game and its main challenges. But the meaning is not always clear. It is unclear what game mechanics are and how the term can be used in game analysis".

Yet, educational components are expressed through a game artefact and their inherent mechanics are embedded within the actual game mechanics. Gee (2003, 2005) purports that gameplay mechanics comprise repeated elaboration and rehearsal across increasing challenging game levels. Retention of information is increased as a result of the learners' personal experience and their increased ownership of the material (Gee, 2003). Conformances to pedagogical practices mean SGs should have knowledge transference as a core part of its game mechanics (Gredler, 2004; Shaffer, 2005; Shute, 2009). Evidence has suggested that interactivity greatly increases student motivation to learn, retain and apply the information presented to them (Ritterfield & Weber, 2005; Wong, 2007; Foster, 2008). However, interactivity alone is not sufficient to instil learner motivation states Greenwood-Ericksen (2008). He found that even where a game had full narrative and interactivity, learning efficiency was only achieved when the game induce leaner engagement through enjoyable and meaningful play. As a consequence it is difficult to dissociate game mechanics from educational components at implementation level since they form an entity which functions to educate and entertain through a single compelling experience.

The boundaries between entertainment and pedagogy are therefore blurred to the point where both game and learning components serve as the building elements of a single experience. As integral constituents of games for lifelong learning these mechanics form standards fundamental to the planning, prioritisation of objectives, assessment and actions that is the basis of the domain/topical discourse leading to knowledge discovery and acquired skills. These standards are also the avenue to interoperability, which must take into account a learner-centric perspective. Which pedagogical philosophy to use is not the remit of this chapter, rather the methodology taken is that through an experiential curriculum one constructs the cognitive skills to uncover knowledge, the ability to perform social and civic engagements and the attitude of reflection. Consequently, it becomes essential that we understand the means through which pedagogical outcomes are achieved and interpreted through engaging and enjoyable game-play. While the principles of learning and game-play are seemingly contradictory - game-play offers enjoyment, interaction and immersion while learning frequently offers constraints, frustration and may include reflection - they coexist in SGs (Huynh-Kim-Bang, 2011). Game-play expressed through game mechanics concretely describe in-game activities and represent a level of abstraction at which the formal mapping of gaming and learning can be established.

In order to better understand, develop and implement SGs, it is necessary to consider the entirety of the SG ecosystem that enable in-depth and multi facet analyses. The three reference points identified for this analysis are the components included in a digital game, the environment where the digital game will be implemented and external factors that reach beyond the core technical aspects of a digital game (Figure 1), with focus on three specific elements, respectively game mechanics, interoperability and assessment. Standards and interoperability apply to each of the ingredients of the three main topics. This generates a multidimensional model that

Figure 1. The serious games ecosystem



needs to be tailored according to the objectives of the game. Moreover, as some of the ingredients cross the boundaries of the three topics, this multidimensional approach highlights these interconnections.

From Utilitarian to Acceptance

While there is growing acceptance by many institutions on the benefits of SGs for education few have embraced SGs into their formal curriculums. A study by Baek (2008) identified several major issues of which some could be mitigated by a more effective game design strategy. A crucial finding revealed the lack of suitably matched games to current taught material as the primary reason why games were not integrated into the curriculum. The study found that most games were designed to focus on entertainment rather than education. Moreover, those games usually offer a restricted set of assessment instruments that may not fit the instructors' pedagogical model. The findings also indicated teacher's felt at a loss with technicalities of the software and how they could evaluate student performance in the game world. Acceptance therefore relies on games designed to fit the teacher's need and the primary requirements of education along with supplementary material implementation and utilisation of the software. Curriculum inflexibility and time pressure were another two findings which interoperability could resolve.

Acceptance is directly related to the ease of the development and implementation processes. We therefore argue that the successful development and implementation of digital games are critically related to standardisation. Both academic and business entities agree that interoperability enables products to work collaboratively, providing assurance that a product can deliver a certain level of performance and tools, while reducing the Total Cost of Ownership (TCO) for the learning solution. Indeed many open questions have emerged in relation to the following main topics:

- Different standardisation bodies creating different standards result in overheads, such as the format war related to the HTML5 specification that does not specify which video formats browsers should support (H.264 versus WebM and Theora) In addition, standards such as H.264 are only partially open because they are conditioned by various patents and mandatory association membership. Should we reuse existing standards or are new ones required?
- Relevant *de facto* standards are often of a proprietary nature and closely tied to particular pieces of hardware, e.g. game consoles and game controllers, should we adopt them?

- Standards awareness and acceptance does not translate into standards implementation. Some companies find protocols too extensive and complex, performing operations that were not relevant to games and slowing the performance of the system. What are the real benefits of and standard adoption? As a serious games buyer, what are the benefits of requiring standards compliance to serious games developers?
- Some prefer to develop derived protocols that include only those functions needed to support their application; do we need a universal serious games standard? Or, in contrast, do we need a general serious games framework enabling the implementation of the framework with different standards particularly to the application scenario?

Many of these questions have appeared in the technology enhanced learning community particularly on the topic of reusable educational materials and Learning Objects (LOs) (Polsani, 2003; Northrup, 2007; Wiley, 2007). The LO paradigm offers a new perspective on modularisation educational materials. LO adopters have considered interoperability among different VLEs and tools, in order to preserve the investment made in the content development. To achieve LO interoperability several standards and specifications have been developed taking into account aspects including tagging, packaging, deploying, communication, etc. For example, e-learning standards such as IMS Content Packaging (IMS-CP) and ADL Shareable Content Object Reference Model (SCORM) addresses some of the aforementioned issues to avoid specific VLE vendor lock-in/ development tool and to simplify content deployment/interoperability for standard-compliance. Serious games can be seen as a particular type of educational content, thus it is feasible to adopt as an starting point the standards and methodologies that have been put in to practice.

Additionally, serious games can be a practical assessment tool providing a means of communication between games and an external tool (usually a Learning Management System) is available to facilitate assessment, the reporting process and analysis of players' actions. Though there is no widely adopted specification or standard related to the communication between serious games and externals tools, the LO experience can be used as a starting point, for example reusing SCORM communication mechanisms.

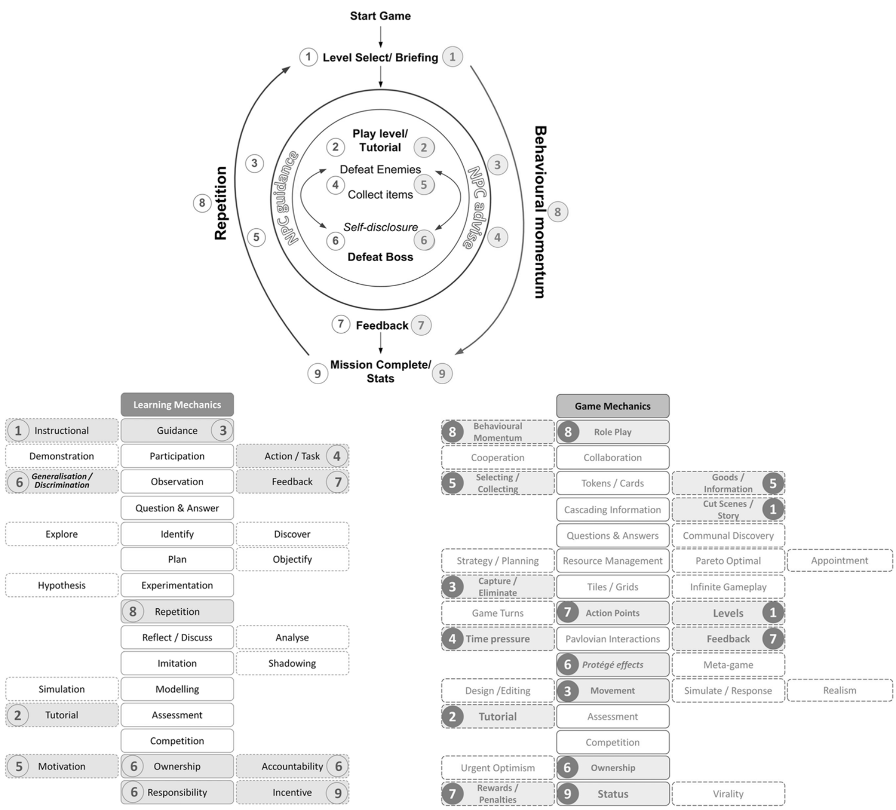
PRACTICAL AND TECHNICAL ASPECTS

Digital games have become a reference point in education and training. Unfortunately this rapidly growing domain includes complex software technology with a lack of visibility into its internal architecture and in the context of pedagogical use.

Game Mechanics and Learning Mechanics Interchange

Deconstructing a Serious Game into its pedagogical elements and its game mechanic nodes is often fraught with conflicting arguments of interdependencies. Figure 2 illustrates the relationships of key mechanics present in learning theories and that of games (serious and otherwise). At a glance, the nodes of learning and gaming mechanisms show no obvious direct interchange or relationships between learning theories and actual game mechanics. Hence, the diagram is exemplified by way of mapping a well documented game Re-Mission (available at www.re-mission.net/). The reading of the pedagogy-game mechanic model can be viewed top down for simplicity, with core components running centrally down from the lead nodes of “Learning mechanics” and Game mechanics” respectively. The leaf nodes on either side can be viewed as subsets of the core.

Figure 2. Concept map relating learning mechanics to game mechanics. The illustration abstracts the gameplay loop of Re-Mission. The coded numbers signposts the type and sequential nature of the game and learning mechanics.



Re-Mission game mechanics follow a third-person shooter genre where the game-play is repetitive and sequential in order. Cut scenes explain the upcoming mission, status and any relevant in-game information at the start of each level. The framework identifies this as an instructional learning mechanism. The player is merely an observer here, much as in a lecture room setting. Once in-game the player must complete the tasks described in the previous cut-scene. This may require additional knowledge of previously unknown mechanics and an NPC (non-player character) will then provide advice and guidance where needed. The framework considers this the layer of understanding. Tutorials act as "safe" learning zones to test the player's understanding tested and guidance is offered when mistakes are made. Having demonstrated the required competency the player enters into the game-play proper. Players subsequently use their acquired knowledge to complete the level. This constitutes the bread and butter of game-play and how the player spends the vast majority of their time. However, occasionally the player will be asked to manipulate taps which send messages to the virtual patient whose body provides the battleground for the current level. Through this mechanism the player's character provides the patient with advice which possibly applies to the user's own treatment. For example, having seen the negative consequences for poor treatment adherence, the player must remind the virtual patient to take their medication. Essentially a protégé effect is created as a consequence of self-disclosure leading to behavioural momentum where the player, motivated by their new conduct, teaches another the correct set of actions. On completing a level basic feedback in the form on level stats are provided and the player can then choose to proceed to the next level, facing the next behavioural outcome.

The game mechanics identified so far only represents a fraction of the wide spectrum of gaming mechanisms that could potentially be pedagogically oriented in SGs. While some are already incorporated many of these mechanics were not specifically developed for SGs but adapted from entertainment and casual games. It is more than likely one game mechanic can be mapped onto various learning mechanics and vice-versa. The proposed approach can be used to investigate Serious Games mechanics over three main dimensions:

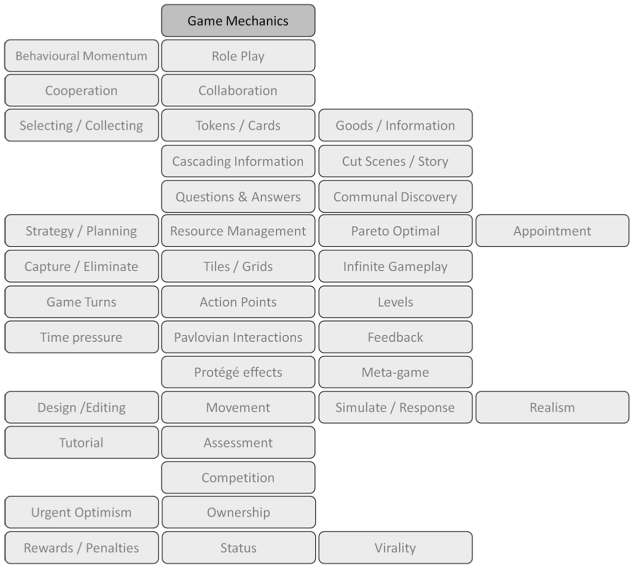
- What are the pedagogical theories relevant to serious gaming and more importantly how do they map onto learning mechanics?
- Learning mechanics are commonly structured to target a specific learning experience. How do they map onto a ludic structure?
- In the same way game patterns have been identified so as to explore the structure of games, can these also be used so as to identify strategies for SG development?

Game Mechanics and Learning Mechanics Characteristics

A definition of the concept of Game Mechanics has been provided by several authors (Zimmerman, 2003; Fullerton, 2004; Hunicke, 2004; Bjork, 2005; Sicart, 2008), yet accepted definitions in the field do not provide a single, dominant approach that encompasses all these aspects. The perspective undertaken herein considers that game mechanics (Figure 3) are designed to enable players to interact with rules, and as more formal properties of a game such as game goals, player actions and strategies, and game states to produce an enjoyable gaming experience. Furthermore, interaction of game mechanics determines the complexity of user interaction within a game. A brief summary of elemental game mechanic characteristics is presented here:

- **Rewards:** Feedback a player would receive for a worthy action. Used to incentivise the player to progress in the game. Rewards are designed to sustain engagement and to satisfy the player.
- **Protégé Effect:** Explores learners' tendency to work harder for their teachable agents (i.e. their avatars or alter ego) than for themselves; it has significant benefits for learning and engagement.
- **Resource Management:** Establishing relative values for different types of resources. Games that use this mechanic often have several concurrent transactions and the challenge involves making the best decision given the resources and time constraints.
- **Tokens to Act as Cards or Random Elements:** To add the element of surprise and act as a randomiser, cards and tokens can be used to add a layer of unpredictability to the game and determine game states.
- **Cascading Information, Cut Scene, Story:** Information released in minimal snippets to gain the appropriate level of understanding at each point during a game.
- **Questions and Answers**: Used within the gaming environment as a basic, yet effective means of interacting and engaging with the player to facilitate learning.
- **Behavioural Momentum:** Used to give confidence and motivate players to continue the game.
- **Role Playing:** Rely on mechanics to establish the effectiveness of actions within the game, depending on how well the player assumes and develops their role as a virtual character.
- **Collecting:** Elements of virtual knowledge, competencies, or rewards can be represented by virtual objects, which can be collected by the player.

Figure 3. Game mechanics



- **Game Turns:** A segment of the game set aside for certain actions to happen before moving on to the next turn, where the sequence of events can largely be repeated.
- **Tile Based and Physical Movement:** Based on how players or elements in games move from one point to another. Tile based movement allow players to move and explore a world which is divided into tiles in turns and amount of tiles moved. Physics based movement provides a greater sense of immersion as players feel as though they are inside the game environment. The focus is no longer about the game tiles but on what players do with them within the limited resources and time.
- **Capture/Eliminate:** The strength of the player is defined by how many points or counters the player has captured. This is most prominent in action, strategic or war based games. Many board games also use this technique.
- **Quick Feedback:** Shows the user what they have just done, and gives them instant gratification (the feel-good factor) of things happening after they have completed a task. Allows the user to feel understood by the game; by giving a user power, the game fulfils a natural human desire.
- **Pavlovian Interactions:** Follows the methodology 'easy to learn, hard to master'. Meaning the game is simple to pick up and play, however, increases its difficulty as the user advances through the game. Used to 'hook' gamers due to its replay value and challenging environment.

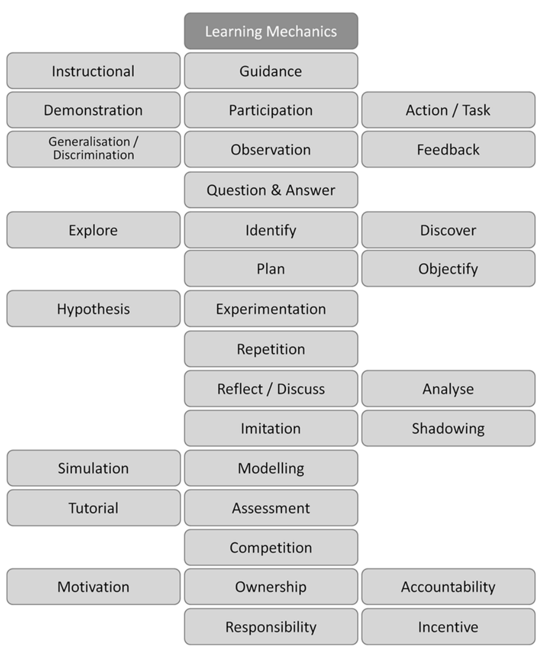
- **Action Points:** Control what the user may do during their turn in the game by allocating them a budget of 'action points'. Actions points allow users' time to think of their next and future moves, the game gets the user into a strategical mind set when playing.
- **Tile-Laying:** Often drawn by the player for strategic positioning in order to achieve a set personal objective or game based goal.
- **Appointment:** A mechanic in which to succeed a "player" must return at a predefined time to take a predetermined action. Simple and powerful mechanic to influence the player's behaviour.
- **Communal Discovery:** Involves an entire community working together to solve a problem. Has an incredible opportunity to positively influence the games' usage and acceptance. Essentially crowd sourcing with communal incentives to rapidly create a large, self-propagating network.
- **Urgent Optimism:** Used to elicit a desire to act immediately to tackle an obstacle combined with the belief that it has a reasonable hope of success.
- **Virality:** Mechanics to grow player base which if done right should enrich gameplay. Also designed to reinforce retention.
- **Meta-Game Mechanic:** Rewards or improvements that can be earned during the actual game-play and/or outside of it, that carries over to repeat plays.
- **Status:** Provides a sense of belonging or meaningful empowerment. Multiple forms of status, such as titles, levels, tiers, rank not just globally but also locally within a community.
- **Ownership:** Used to create loyalty of the gaming pool.
- **Infinite Gameplay:** Games that have no explicit end. Most applicable to casual games that can refresh their content or games where a static (but positive) state is a reward of its own.
- **Cooperation/Collaboration:** In cooperative games, the mechanics require players to work with one another but their goals are different, and not all players are guaranteed to benefit equally. In collaborative games, players share common goals and outcomes; players either win or lose together. Cooperative games exist on the spectrum between competitive and collaborative games, where gamers are rewarded for group-oriented strategies only when it is in their own self-interest.
- **Pareto Optimal:** A mechanic where the outcome is one in which no player could be better off without another becoming worse off. The mechanic occurs in a number of conflict, negotiation economic, management and quantum games. Pareto efficiency is reached if the games' outcome is shown to deliver a Pareto optimal allocation of resources.

These are just a myriad of game mechanics that change the dynamics of gameplay and act as the core building blocks used to construct the game layers. By having a deeper understanding of how these game mechanisms work new game dynamics specifically for learning can be discovered.

Brief descriptions of the core learning mechanics (Figure 4) are presented hence:

- **Instructional:** Where a facilitator or teacher provides learner support within a framework determined by the course leader. Specific learning objectives are followed through sequentially. A generic instructional model such as ADDIE (Analysis, Design, Development, Implementation, and Evaluation) can be used.
- **Guidance:** A means to help students see the structure, links and direction of the course material.
- **Demonstration:** A pedagogical method related to problem-based learning.
- **Participation:** A (active learning) process of engaging with the learning task at both the cognitive and affective level.
- **Action/Task:** An approach to learning involving individuals working on real projects, possibly with group support (collaborative/cooperative learning) to assist members reflect on their experience and to plan next actions.

Figure 4. Learning mechanics



- **Generalisation/Discrimination:** In psychology this relates to the process by which people learn to make different responses to different stimuli. Behaviourists describe this as classical conditioning (also Pavlovian or respondent conditioning, Pavlovian reinforcement). In some ways this can be viewed as induction. Induction (inductive learning/teaching) aims at equipping learners with background information so that they might become effective in their role sooner.
- **Observation:** Observational learning (also referred to vicarious learning, social learning, modelling) is based on the concept that learning occurs as a function of watching, retaining and replicating the behaviour of others.
- **Feedback:** Oral or written developmental advice on performance so that the learner has a better understanding of values, standards, criteria, etc. Linked with formative assessment.
- **Question and Answer:** An active learning mechanism linked with participation that encourages learners to use the questioning strategies to assess what they have learned, to develop their thinking skills.
- **Explore:** A mechanism that encourages the learner to explore and experiment to uncover relationships, with much less of a focus on didactic training (teaching students by lecturing them). Exploratory learning approaches are considered most appropriate for teaching generalised thinking and problem-solving skills, and may not be the best approach for such things as memorisation (or repetition). Is related to constructivist theory.
- **Identify:** A social learning theory (or cognitive theory) that posits learning will most likely occur if there is a close identification between the observer and the model and if the observer also has a good deal of self-efficacy.
- **Discover:** An inquiry-based learning mechanic (from constructivist learning theory) where the learner draws on past experiences and existing knowledge to discover new facts and relationships to solve problems. As a result, learners are more likely to retain concepts and knowledge in contrast to transmissionist learning. Related to: guided discovery, problem-based learning, simulation-based learning, case-based learning, and incidental learning.
- **Plan:** A conditional no-regret learning mechanic associated to Bayesian learning and hypothesis testing. As with a given type of game and a given amount of information, there may exist no learning procedure that satisfies certain reasonable criteria of performance and convergence. The learner has to strategically manage his or her resources to achieve an aggregate learning outcome.
- **Objectify:** Termed behavioural objectives (commonly referred as learning outcomes). Its meaning ranges from exact, measurable outcomes of specific learning experiences to more generalised statements for courses of study.

Learning objectives can be made more difficult or demanding depending on the degree of understanding or levels of experience of learners. One can change the active verb to a more complex one or to add specific conditions or limits.

- **Hypothesis:** Often related to acquisition-learning it is a method to develop competency in a specific subject area. Most contemporary use in education relates to performing a task and being able to debate the underpinning knowledge and understanding.
- **Experimentation:** Typically involves laboratory/practical classes, this type of teaching is often used in curricula in experimental sciences, biomedical and engineering disciplines, which is broadly intended to offer training in techniques and learning how to carry out experimental investigations. Associated to experiential learning.
- **Repetition:** A method that uses traditional curriculum for students to practice at home or onsite. Although significant practice is performed, higher order learning is not involved.
- **Reflect/Discuss:** Consideration of an experience, or of learning, to enhance understanding or inform action. Learners often compile logbooks to record their reflections on learning activities.
- **Analyse:** Related to diagnostic tests to identify weaknesses, and used so that these might be addressed in a more focused manner.
- **Imitation:** This is similar to role-play where a planned learning activity requires participants to take on the role of individuals representing different perspectives (e.g. mock interview) to meet specific learning objectives, such as to promote empathy or to expose participants to a scenario in which they will have to take part in the future.
- **Shadowing:** Often used in medical sciences where the student shadows their mentor during general practice or in operating theatres. Shadowing is also a form of learning through apprenticeships. Associated with experiential learning.
- **Simulation:** Often associated with role-play it is increasingly used with ICT-based learning activities for decision-making to simulate cause and effect.
- **Modelling:** A means to test a hypothesis, to evaluate a concept or as a form of observational learning.
- **Tutorial:** Used with different meanings according to discipline, type of institution, level, and teaching and learning method that involves a tutor or peer.
- **Assessment:** Measurement of the progress and achievement of a learner (typically through quizzes, examinations or even projects). For example, formative assessment allows learners to gauge their proficiency thereby to improve

their self-regulatory skills. Rather than expressed as marks or grades, words are used to convey or reveal information, which can then be used diagnostically (e.g. summative assessment).

- **Competition:** Competitive learning is often used as an extracurricular activity to develop creativity and problem solving skills. Game theory offers techniques for formulating competition between parties that wish to reach an optimal position.
- **Motivation:** In terms of extrinsic motivation, marks and grades are used to target students who are more concerned with the numeric value of their work, and those that seek status. Intrinsic motivation typifies students who enjoy challenge, want to master a subject, are curious and want to learn. They are inspired to achieve high grades even when the task does not inspire interest.
- **Ownership:** Associated to constructivist theory where knowledge is internalised by learners through processes of accommodation and assimilation, they construct new knowledge from their experiences.
- **Accountability:** Can be viewed as autonomy where learners take responsibility for and control of themselves and their learning, including being less spoon-fed. May also include elements of learners taking responsibility for determining and directing the content of their learning. Related with open learning mechanics.
- **Responsibility:** Often related to self-directed learning where the learner has control over educational decisions, including goals, resources, methods and criteria for judging success. Often used as a learning situation where the learner has some influence on some of the learning aspects.
- **Incentive:** Incentive learning is the process via which learners update changes in the value of rewards. Such methods are useful in changing the behaviour of the learner, where a stimulus-response habit mechanism and a goal-directed process are the two learning mechanisms. The first is learning about the instrumental contingency between the response and reward, whereas the second consists of the acquisition of incentive value by the reward.

Assessment and Interoperability

A critical area of interest to the digital game-based learning communities is standards for interoperability. The entertainment industry, to date, has expressed different interests regarding interoperability standards. While the academic community has a strong interest in ensuring that various simulation systems can work together and integrate with the already established e-learning tools in the organization. In contrast, the entertainment industry places strong emphasis on developing proprietary systems and standards that preclude interoperability. Unlike the billion-dollar entertainment video game industry, which has responded to increased product demand by developing increasingly complex and costly games, the SG industry has followed an approach of cost containment and technology simplification (Moreno-Ger, 2010). Commercial *de facto* standards have not sought interoperability between independent systems, but have attempted to allow independently produced software titles to integrate with the same user front-end software such as operating systems, Web browsers, or graphic libraries. Subsequently, these standards enable the same software to run a variety of game applications. However, collaboration of heterogeneous software developers leads to interoperability issues, which represent a major barrier in the software development sector. Obstacles to heterogeneity arise from the fact that software developers seldom share the same semantics for the terminology of their models. Moreover, they use various collaboration scenarios with different organizational constraints.

Eliminating or alleviating fragmentation is the grail of SG development. Fragmentation arises from game domain use and user individual preferences. As with the core content that governs the game's mechanics the SG development and deployment lifecycle must consider portability across software platforms, devices, libraries, and user customization. Importantly, SGs being bespoke learning ecosystems have to cater for the ease of content update and qualified assessment because it has a direct impact on the addressable market share and software development costs.

SCORM (Sharable Content Object Reference Model) makes possible the sharing of distributed learning content across learning management systems that conform to SCORM. Its development and implementation was clearly a vital first step in achieving the long-term vision of providing high quality training and education on demand (Shane, 2010).

SCORM has become an international *de facto* standard in large measure because the goal was the establishment of a consensually negotiated foundation for a community to come together to address community goals: accessible, interoperable, durable, reusable content for learning and performance aiding (Roberts & Gallagher, 2010). In addition, the ADL SCORM 2004 3rd edition has been promoted from simple specification to *technical recommendation* by the ISO/IEC JTC1 SC36 committee in the form of ISO/IEC TR 29163 documents family.

SCORM specification covers two particular topics related to SGs: package and deployment, and communication between a serious game and the Learning Management System (LMS). The serious game is conceived as a SCO object, and considering the SCORM Content Aggregation Model it can be deployed in multiple commercial and open source LMS platforms already available. In addition, SGs can generate a great amount of tracking information that can be used by the instructor to evaluate the student play session. Using the SCORM Runtime Model a SG can set some of the cmi.* properties.

In particular, the following CMI properties have been identified:

- **cmi.completion_status:** This property is used to track if the SG has been finished or not.
- **cmi.success_status:** This property is used to track, once the SG has been completed, if the student has achieved the learning objectives during the game play session or not.
- **cmi.core_score_raw:** In contrast to cmi.success_status, this property can be used to evaluate the overall performance of the student's game play using a numerical scale.
- **cmi.interactions:** This is a collection of properties, that is, multiple values can be collected inside this property. In contrast to cmi_score_raw and cmi.success_status that provide a coarse-grained evaluation of the student's performance, cmi.interactions.* can be used to provide a fine-grained or detailed report of the student game play session and its relation to the SG learning objectives.

These properties (and the rest of SCORM data model) can be used in the eAdventure authoring tool. This way, the internal game state can be translated to a platform neutral data model. Moreover, e-Adventure games sent the information back to the LMS using the SCORM Runtime API, so the game tracking information can be reviewed or used by other tools that are hosted in the LMS.

Strategies for Engineering Serious Games

Serious games development and implementation remain an open challenge within educational environments. Serious game applications are usually complex interactive real-time systems, which are non-trivial to implement. Serious game production has a multi-disciplinary nature, because – in addition to software development – a serious game production process can include, besides areas such as graphics design and implementation, sound engineering, and story design (Stănescu et al., 2011), critical elements that relate to education: game mechanics, learning mechanics, serious game assessment. The research carried herein reveals the challenges that arise at different levels. Monetary and time constraints have been identified among the most relevant impediments in serious game development. Moreover, serious games differ in complexity from commercial games, as they require critical constructs that translate the learning objectives. Corroborating these with the fact that most educators do not possess the advanced IT skills required to develop a game, it becomes mandatory to search for more viable alternatives.

Even if each game is a self-contained entity and its development is a separate and distinct process, an approach were each game is to be built from the ground upward or where no work from one game could possibly be of use for the next, is no longer feasible. Therefore, it has become crucial to generate new strategies that would support a successful development and implementation of serious games through the creation of functionally interchangeable items adapted to the learning environments, the adoption of standards that impact serious games, and of methods that would make game components interchangeable, without having to alter the item to make the new combination work, because each interchangeable part had been designed to have functional characteristics that are equivalent in performance and durability without alteration. It is important to support inter-changeability that considers the position of the development companies and of the educational actors towards standards adoptions in an effort to understand how to create cost-efficient, flexible interoperability solutions. Open systems architecture represents also an alternative because it focuses on a modular design that defines key interfaces within a system using widely supported, consensus-based standards that are available for use by all developers and users without any proprietary constraints.

Under these premises, the authors advance for analysis the use of a standard-compliant graphic editor as a multi-benefit approach for learning based on the belief that many properties and features common to all games and to all platform games can be extracted from their particular context and given an abstract form that has lost all reference to concrete circumstances and applies not only to one game but to all. Generalizable components of a game (such as graphics, sound, game mechanics) can be reused to produce many different games when integrated into a single platform. This approach brings forward a new challenge: the effectiveness of such a platform that integrates serious game development tools.

Even though game development environments will not be able to completely alleviate the need for experiences game developers, they will lower the bar of entry for tech savvy educators, allowing them to customize existing games, and at the same time use these games as a learning tool on how the game development environment works, and how to create new games. Given the digital nature of these games, there will be a great incentive for educators to experiment and learn from them, as they can easily roll back their changes to a previous working copy of the game, as well as share their work with other fellow educators.

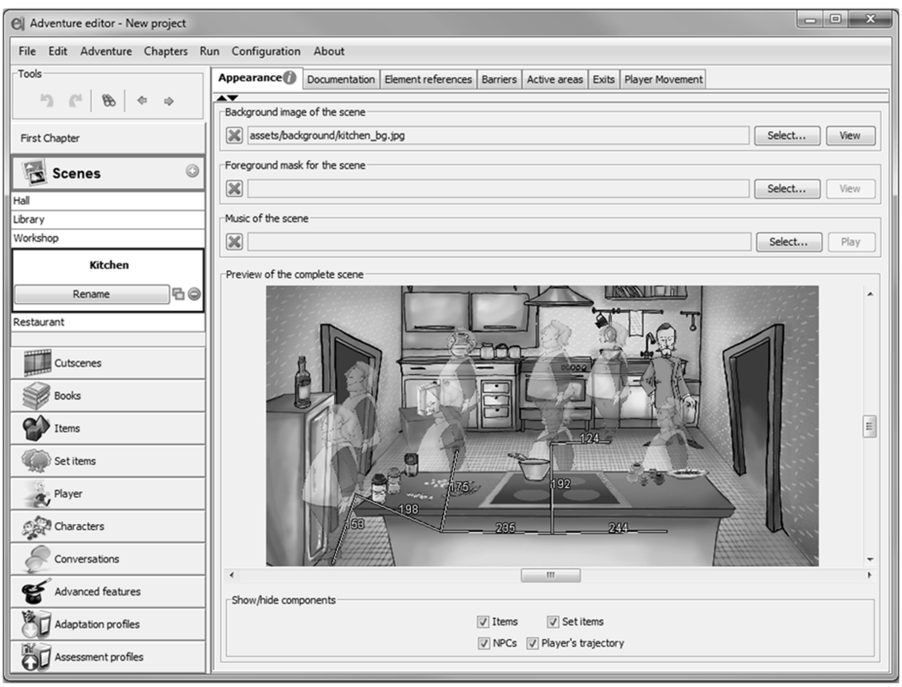
CASE-STUDY: E-ADVENTURE PLATFORM

The practicalities of this research are extracted through a case study based on the eAdventure platform (available at: http://e-adventure.e-ucm.es). eAdventure is a platform originally focused on the development of classic point&click adventure computer games with educational purposes. The platform focuses on adventure games because this specific game genre has been previously identified in the literature as the ideal genre for learning (Ju, 1997; Amory, 1999; Amory, 2001; Dickey, 2006). However, eAdventure also supports other types of 2D games based on *point&click* or *drag&drop* interactions, including basic simulations of procedures (Moreno-Ger, 2010).

It provides a teacher-centred framework for the development of educational video games focused on the reduction of the costs and the needed technical background by offering a visual drag & drop interface to create the games (Torrente, 2010) (Figure 5).

To extend the insights of this case study, several sets of interviews have been carried out within three universities: Herriot Watt University in Edinburgh - Scotland, Carol I National Defence University in Bucharest – Romania, and Universidad

Figure 5. The eAdventure game editor



Complutense de Madrid – Spain. In total, nine semi-structured sets of interviews were conducted. The majority of interviews were carried out in person while some were conducted via desktop teleconferencing using Skype®.

This empirical, exploratory study attempts to address the strengths and weaknesses related to a standard-compliant game editor, as well as to identify core learning mechanics and game mechanics that eLearning practitioners consider critical which in turn may provide a basis for the enhancement of the current development practices of game editors.

The participants in this study were selected from various subject areas such as computer science and engineering, military training, medicine, music, maths, and foreign languages. Five sets of interviews were carried out with experts that had no prior experience with eAdventure, while four sets of interviews were carried out with experts that have participated in specialised training for using the eAdventure editor. The following sub-sections describe the results of the case study, with a special focus on measuring to which extent the eAdventure platform may be used to support the requirements identified in the previous section.

Impact of Learning and Game Mechanics

The respondents for all the interviews were asked to report which learning mechanics and which game mechanics they considered especially relevant in their fields. Each mechanic was ranked on a scale from 1 (least relevant) to 5 (very relevant). The results of the interviews in relation to learning mechanics identified (Summarized in Figure 6a) that the most relevant mechanics were: *Repetition; Identify; Question&Answer/Feedback; Simulation/modelling; and Assessment*. *Competition* and *Accountability* were considered least relevant.

The respondents were also queried about how relevant each game mechanic could be within their field (Summarized in Figure 6b). The responses indicated that as the five most relevant individual game mechanics were: *Cascading information/ Cut Scenes; Simulate/Response; Question&Answer/Feedback*; *Assessment; and Pavlovian interactions/ Feedback.* The least relevant were *Protégé effects* and *Meta-game.*

By comparison, the analysis revealed that *Question&Answer/Feedback* and *Assessment* were in the top five candidates for both learning and game mechanics.

Implementing Learning and Game Mechanics with eAdventure

The sets of interviews targeting users with experience using eAdventure asked participants about their perceptions of whether eAdventure was a viable game engine to support the different game and learning mechanics (See Figure 7).

Figure 6. Perception of the importance of the individual (a) learning mechanics (b) game mechanics

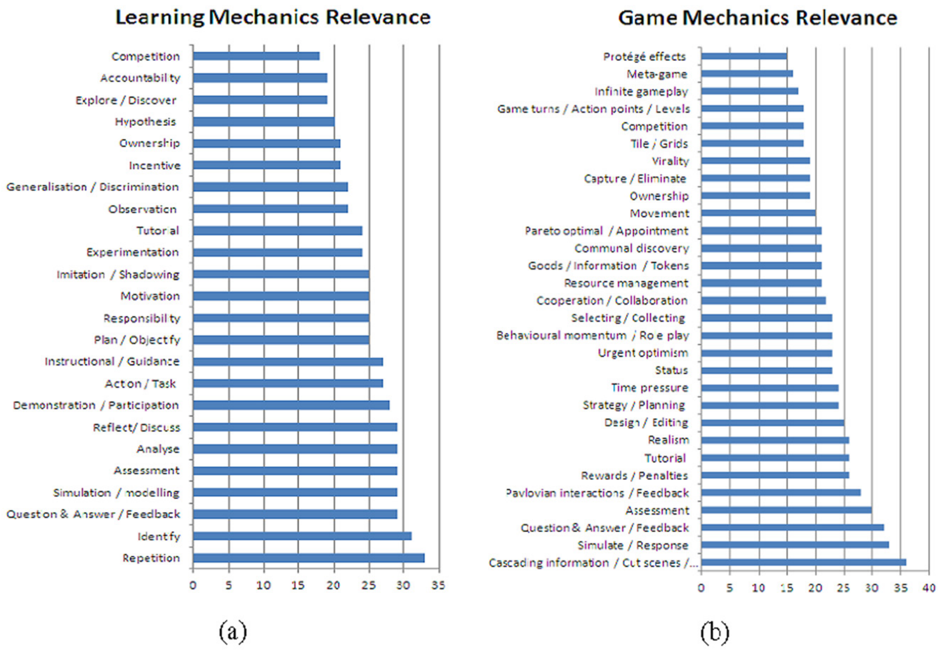
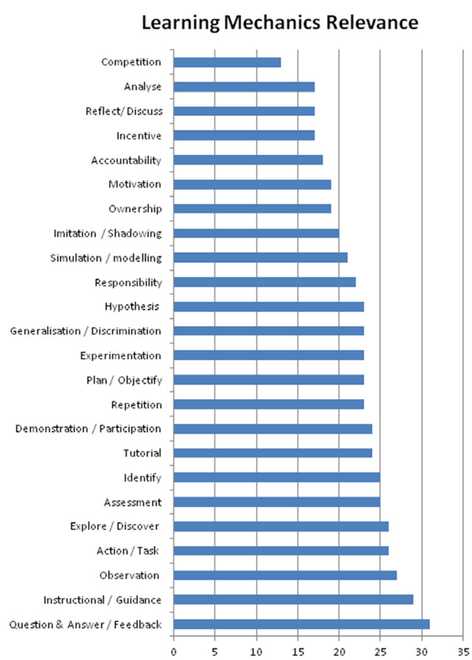


Figure 7. Applicability of each learning mechanic in eAdventure



The experts were asked to grade how easy it would be to create eAdventure games that applied each individual mechanic. Each mechanic was graded in a scale from 1 (impossible) to 5 (easily). When asked about learning mechanics (See Figure 8) the experts identified that the 5 most natural learning mechanics applicable with eAdventure were *Question & Answer/Feedback*, *Instructional/Guidance*, *Observation*, *Action/Task* and *Exploration*. Among them, *Question&Answer/Feedback*, *Instructional/Guidance* and *Observation*, received average scores greater than 4. On the other hand, *Accountability*, *Incentive*, *Reflection*, *Analysis* and *Competition* received the lowest scores, and only *Competition* received an average score lower than 2.

The experts also rated the game mechanics, highlighting that *cutscenes* and other forms of continuous flows of information were simple to do, as well as interactions based on *Questions & Answers*, *Roleplaying* and *Tutorials*. Other game mechanics identified as reasonably easy to implement were *Assessment*, *Time Pressure*, *Selecting/Collecting* and *Design/Editing*.

In contrast, the experts evaluated that eAdventure was not appropriate for other mechanics such as *Collaboration, Communal Discovery* and *Competition* (since eAdventure only allows the creation of *single-player* games). Other genre-specific game mechanics, such as *Tiles*, *Grids*, *Game Turns*, *Action Points* or *Levels* (not common in *point & click* adventure games) also received very low scores.

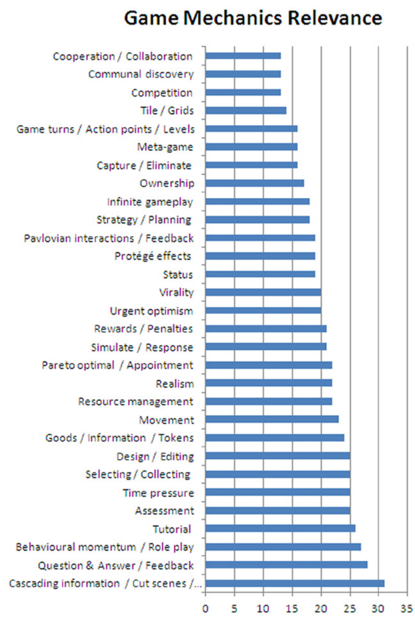
Support for Assessment and Interoperability

The eAdventure platform was specifically designed to create educational games that could be integrated in Learning Management Systems. It includes assessment mechanisms that allow the identification of relevant game states. These states can be used to generate a human-readable assessment report, assign grades to final states or even compute grades as the game progresses (Moreno-Ger, 2008).

Furthermore, e-Adventure allows exporting the games as standards-compliant Learning Objects adhering different standard, and hence, making possible the deployment of the created games in a wide range VLE or stored them in LO repositories (Torrente, 2009).

In addition to allowing the packaging of games as Learning Objects, eAdventure games can also be exported as SCORM-compliant SCOs, with the ability of opening a connection to the webserver and sending assessment information through this channel. In particular, it is possible to submit values for the fields “Completion Status” and “Success Status”, which can be used for assessment or sequencing decisions. Due to eAdventure’s architecture, these assessment messages can be sent to

Figure 8. Perception of the importance of the individual game mechanics



different servers supporting different standards (e.g. SCORM 1.2, SCORM 2004 or LAMS), facilitating interoperability even across systems that comply to different standards or specifications (del Blanco, 2011).

The interviewed experts were also asked about their perceptions of the SCORM-based assessment system, and their responses were mostly positive regarding its effectiveness. Two of the users, however, considered that the strict rule-based assessment system was too restrictive, and did not allow for creative assessment approaches.

Limitations

Working with eAdventure allows practitioners to create their own games, but it also limits them when choosing which learning and game mechanics to apply. Focusing on learning mechanics, the reviewers indicated that eAdventure games were not adequate to exploit learning approaches such as, *Accountability*, *Incentive*, *Reflection*, *Analysis* and *Competition*. Many of the lower graded learning mechanics could be compensated with the context of the games. E.g., even if an eAdventure did not foster *reflection* by itself, the gameplay sessions could be followed by instructor-led debriefing sessions in which reflection could be promoted. However, other mechanics such as Competition do not really match the *single-player* nature and the slow pace of typical *point&click* adventure games.

The limitations become even more apparent when trying to cover the different game mechanics. A single game can never exhibit all possible game mechanics (as some of them are directly opposite), and game genres tend to exhibit well-defined sets of game mechanics. Given the origin of eAdventure as a toolset focused solely on *point&click* adventure games, many game mechanics are not natural within the genre and are therefore poorly supported by eAdventure.

This is consistent with the responses of the expert reviewers, who assigned very low scores to the feasibility of genre-specific mechanics such as *Tiles*, *Grids*, *Game Turns*, *Action Points* or *Levels*. Some other limitations are a consequence of eAdventure allowing only the creation of single-player games, which affects the feasibility of mechanics such as *Collaboration, Communal Discovery* and *Competition*.

These limitations resulted in some of the interviewees suggesting to extend the same type of editor to other types of games, including support for tiled-based games, physics engines or interaction with haptic devices. The addition of collaborative activities or multiplayer options was also requested by the interviewees.

In addition, while the participants that had received previous training using the eAdventure platform considered the system as easy to use, 20% of the participants without prior training considered that the eAdventure Editor was not user friendly and intuitive and some interviewees suggested including step-by-step wizards for different common tasks.

DISCUSSION AND CONCLUSION

The field of digital games is abound with open challenges, in particular learning, and necessitate a critical rethink of the strategic elements that determine their effectiveness for learning. Faced with limited streamlined, interoperability-enabled development processes as a consequence, the gaps in implementation that concern the assimilation and acceptance of digital games into teaching and learning leaves many unanswered questions.

Beginning with these issues, this chapter offers a comprehensive overview of game mechanics investigating relevant concepts such as game patterns, or pedagogical constructs in order to determine a spectrum of activities, practices within which digital game mechanics can be identified. The research analyses the key issues in dissociating game-play mechanisms from pedagogical output in order to facilitate the production of a comprehensive methodology through which digital game mechanics could be abstracted from current digital games and mapped onto pedagogical constructs.

A prospective mapping between educational philosophies and games agenda is presented to make aware the interoperability modus from which topical (domain) frameworks or architectures can be structured. The authors analyze interoperability as a critical factor to a successful development and deployment of digital games. Interoperability is achieved through multiple tools and approaches. This implies collaboration at multidimensional levels that would integrate user communities (such as teachers and developers), software, hardware, standards, etc. The reflection of these interconnections translates into a multidimensional interoperability framework that integrates three key elements: the components included in a digital game, the ecosystem where the game will be implemented and external factors that go beyond the core technical aspects of a digital game.

It is relatively easy to design a game, however, designing a high-quality game is very difficult and designing an effective educational game is extremely difficult. Literature has yet to publish an effective/standard framework or pedagogy guidelines to assist educators identify content most suitable to be translated into a playable game. Even though a number of game engines are available educators may not have the technical ability to create useful applications. An educator may seek the expertise of a game company, however, game developers would not normally be cued to the content or possess the pedagogical knowledge. Games companies would additionally weigh the business incentives over educational games against potential audience numbers.

All games are constructed with a set of activities driven by rules that govern the mechanics. In playing the game the player constantly cycles through these mechanics. The (game) rules restrict the player to the gameplay and consequently the game environment. While most game mechanics are applicable across genres, some genres - particularly content dependent SG - may require several specific set of game mechanics.

The research has identified that pedagogy and learning mechanisms are essential in understanding the relationships between learning outcomes and a digital game experience. Digital games introduce significant new requirements for robustness and interoperability, and encourage game developers to better align their practices with the requirements of the educational domain. In addition to new languages and middleware, developing and adopting standards for interoperability could benefit both the developers and the serious games user communities, and facilitate growth of the genre.

In summary:

- Digital games standardisation needs to be strengthened as digital games standards enable software application to interoperate, enable better management and visibility of digital games assets and ensure quality of digital games products;
- All existing standards that apply to digital games need to be identified and analyzed in collaboration with game developers and teachers, in order to streamline successful development and implementation strategies;
- Industry and all stakeholders should give their feedback for the revision of the current digital games standards considering the current technology needs;
- While considering digital games standards, interoperability should be pursued both for hardware and software;
- Due to the wider and wider use of digital game-based products, user safety and security emerges as an important factor and standards should address these issues.

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REFERENCES

Amory, K. (2001). Building an educational adventure game: Theory, design and lessons. *Journal of Interactive Learning Research*, *12*, 249–263.

Amory, K., Naicker, J. V., & Adams, C. (1999). The use of computer games as an educational tool: Identification of appropriate game types and game elements. *British Journal of Educational Technology*, *30*, 311–321. doi:10.1111/1467-8535.00121

Avedon, E. M., & Sutton-Smith, B. (Eds.). (1971). *The study of games*. New York, NY: John Wiley & Sons, Inc.

Baek, Y. K. (2008). What hinders teachers in using computer and video games in the classroom? Exploring factors inhibiting the uptake of computer and video games. *Cyberpsychology & Behavior*, *11*(6), 665–671. doi:10.1089/cpb.2008.0127

Björk, S., & Holopainen, J. (2005). *Patterns in game design*. Hingham, MA: Charles River Media.

Boström, L. (2011). Students' learning styles compared with their teachers' learning styles in secondary schools. *Institute for Learning Styles Research Journal*, *1*, 16–38.

Cook, D. (2006). *What are game mechanics?* Retrieved December 13, 2010, from http://lostgarden.com/2006_10_01_archive.html

del Blanco, Á., Torrente, J., Moreno-ger, P., & Fernández-Manjón, B. (2011). Enhancing adaptive learning and assessment in virtual learning environments with educational games. In Jin, Q. (Ed.), *Intelligent learning systems and advancements in computer-aided instruction: Emerging studies* (pp. 114–163). Hershey, PA: IGI Global. doi:10.4018/978-1-61350-483-3.ch009

Derryberry, A. (2008). *Serious games - Online games for learning*. Retrieved from http://www.adobe.com/resources/elearning/pdfs/serious_games_wp.pdf

Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. *Educational Technology Research and Development*, *54*, 245–263. doi:10.1007/s11423-006-8806-y

Dror, I. E. (2008). Technology enhanced learning: The good, the bad, and the ugly. *Pragmatics & Cognition*, *16*, 215–223.

Foster, A. (2008). Games and motivation to learn science: Personal identity, applicability, motivation, and meaningfulness. *Journal of Interactive Learning Research*, *19*(4), 597–614.

Fullerton, T., Swain, C., & Hoffman, S. (2004). *Game design workshop: Designing, prototyping and playtesting games (Gama Network Series)*. San Francesco, CA: CMP Books.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York, NY: Palgrave Macmillan. doi:10.1145/950566.950595

Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-learning*, *2*(1), 5–16. doi:10.2304/elea.2005.2.1.5

Gredler, M. (2004). Games and simulations and their relationships to learning. In Jonassen, D. (Ed.), *Handbook of research on educational communications and technology* (pp. 571–581). Mahwah, NJ: Erlbaum.

Greenwood-Ericksen, A. (2008). *Learning African American history in a synthetic learning environment*. Doctoral dissertation, University of Central Florida, Florida.

Hunicke, R., LeBlanc, M., & Zubek, R. (2004). MDA: A formal approach to game design and game research. In *Proceedings of the Challenges in Game AI Workshop, 19th National Conference on Artificial Intelligence AAAI '04,* San Jose, CA. AAAI Press.

Huynh-Kim-Bang, B., Labat, L.-M., & Wisdom, J. (2011). *Design patterns in serious games: A blue print for combining fun and learning*. Retrieved December 13, 2011, from http://seriousgames.lip6.fr/DesignPatterns/designPatternsForSeriousGames.pdf

Ingleby, E., Joyce, D., & Powell, S. (2010). *Learning to teach in the lifelong learning sector*. New York, NY: Continuum International Publishing Group.

Järvinen, A. (2008). *Games without frontiers: Theories and methods for game studies and design*. Doctoral dissertation, Tampere University, Tampere, Finland.

Ju, E., & Wagner, C. (1997). Personal computer adventure games: Their structure, principles and applicability for training. *The Data Base for Advances in Information Systems*, *28*, 78–92. doi:10.1145/264701.264707

Moreno-Ger, P., Burgos, D., Sierra, J. L., & Fernández-Manjón, B. (2008). Educational game design for online education. *Computers in Human Behavior*, *24*(6), 2530–2540. doi:10.1016/j.chb.2008.03.012

Moreno-Ger, P., Torrente, J., Bustamante, J., Fernández-Galaz, C., Fernández-Manjón, B., & Comas-Rengifo, M. D. (2010). Application of a low-cost web-based simulation to improve students' practical skills in medical education. *International Journal of Medical Informatics*, *79*, 459–467. doi:10.1016/j.ijmedinf.2010.01.017

Northrup, P. T. (2007). *Learning objects for instruction: design and evaluation*. Hershey, PA: Information Science Publishing. doi:10.4018/978-1-59904-334-0

Polsani, P. R. (2003). Use and abuse of reusable learning objects. *Journal of Digital Information*, *3*(4), 164.

Ritterfeld, U., Vorderer, P., & Cody, M. (Eds.). (2009). *Serious games: Mechanisms and effects*. New York, NY: Routledge.

Ritterfield, U., & Weber, R. (2005). Video games for entertainment and education. In Vorderer, P., & Bryant, J. (Eds.), *Playing video games: Motives responses and consequences* (pp. 399–414). Mahwah, NJ: Erlbaum.

Roberge, G. D., Gagnon, L. L., & Oddson, B. E. (2011). The ideal classroom: A comparative study of education and nursing student learning and psychosocial environmental preferences. *Institute for Learning Styles Research Journal*, *1*, 1–16.

Roberts, E., & Gallagher, P. S. (2010). Challenges to SCORM. In Jesukiewicz, P., Kahn, B., & Wisher, R. (Eds.), *Learning on demand: ADL and the future of e-learning* (pp. 49–70). Alexandria, VA: Advanced Distributed Learning.

Rouse, R. (2005). *Game design: Theory and practice* (2nd ed.). Sudbury, MA: Wordware Publishing, Inc.

Shaffer, D. W., Squire, K. D., Halverson, R., & Gee, J. P. (2005). Video games and the future of learning. *Phi Delta Kappan*, *87*(2), 104–111.

Shane, G. P. (2010). The development of SCORM. In Jesukiewicz, P., Kahn, B., & Wisher, R. (Eds.), *Learning on demand: ADL and the future of e-learning* (pp. 49–70). Alexandria, VA: Advanced Distributed Learning.

Shute, V. J., Ventura, M., Bauer, M. I., & Zapata- Rivera, D. (2009) Melding the power of serious games and embedded assessment to monitor and foster learning. In U. Ritterfeld, M. J. Cody, & P. Vorderer (Eds.), *Serious games: Mechanisms and effects* (pp. 295-321). Philadelphia, PA: Routledge.

Sicart, M. (2008). Designing game mechanics. *International Journal of Computer Game Research*, *8*(2). Retrieved from gamestudies.org/0802/articles/sicart

Stănescu, I. A., Ştefan, S., & Roceanu, I. (2011). Interoperability in serious games. In *Proceedings of the 7th International Scientific Conference "eLearning and Software for Education"*, (pp. 28-29). April 2011, Romania.

Torrente, J., del Blanco, Á., Marchiori, E. J., Moreno-Ger, P., & Fernández-Manjón, B. (2010). <e-Adventure>: Introducing educational games in the learning process. *Proceedings of the IEEE EDUCON 2010 Conference (Special issue e-Madrid)*, 14-16 April 2010, Madrid, Spain.

Torrente, J., Moreno-Ger, P., Martínez-Ortiz, I., & Fernández-Manjón, B. (2009). Integration and deployment of educational games in e-learning environments: The learning object model meets educational gaming. *Journal of Educational Technology & Society*, *12*(4), 359–371.

Westera, W., Nadolskl, R. J., Hummel, H. G. K., & Woperels, I. G. J. H. (2008). Serious games for higher education: A framework for reducing design complexity. *Journal of Computer Assisted Learning*, *24*, 420–432. doi:10.1111/j.1365-2729.2008.00279.x

Wiley, D. A. (2007). The learning objects literature. In Spector, M. J., Merrill, D. M., & Merrienboer, V. J. (Eds.), *Handbook of research on educational communications and technology* (pp. 345–353). New York, NY: Lawrence Erlbaum Associates.

Wong, W. L., Shen, C., Nocera, L., Carriazo, E., Tang, F., & Bugga, S. Ritterfeld, U. (2007). *Serious video game effectiveness*. Paper presented at the ACE '07.

Zimmerman, E., & Salen, K. (2003). *Rules of play: Game design fundamentals*. Cambridge, MA: The MIT Press.

Zollinger, S. W., & Martinson, B. (2010). Do all designers think alike? What research has to say. *Institute for Learning Styles Research Journal*, *1*, 1–15.

Zylka, J., & Nutzinger, H. P. (2010). Educational games in formal education – Results of an explorative study using an educational game in school. *Proceedings of the International Conference on Computer-aided Learning 2010 (ICL 2010)*, (pp. 954-963). 15-17 September, Hasselt, Belgium.

KEY TERMS AND DEFINITIONS

Game Editor: A software tool that enables the creation of games by combining high level constructs instead of coding the game with a programming language.

Game Mechanics: Rules that define the interactions and flow of a game session. They describe interactions, game conditions and triggers in an abstract manner.

Interoperability: The ability of various software components to work with each other in a meaningful and coherent fashion according to their design specifications.

Learning Mechanics: Pedagogical constructs and activities commonly used in education to achieve different types of learning outcomes.

Serious Games: Games that are designed with a primary purpose distinct from entertainment. Usually (and particularly in the context of this work) that purpose is educational.

Serious Game Assessment: The evaluation of the performance while playing a serious game in terms of either in-game achievements or learning outcomes. The assessment may be performed outside the game (with an exam or a debriefing session) or within the game (using the game itself as an evaluation tool).

Serious Game Ecosystem: A set of technical and non-technical elements that define the functionalities of a serious game and impact upon its development and implementation.

Simulation: Replication of real world events, situations, places, etc, in a controlled environment with the purpose of studying interactions and effects between various objects. A simulation could be done either physically (fire drill) or electronically (flight simulator).