Serious Games for education and training

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Abstract

Serious Games (SGs) are gaining an ever increasing interest for education and training. Exploiting the latest simulation and visualization technologies, SGs are able to contextualize the player's experience in challenging, realistic environments, supporting situated cognition. However, we still miss methods and tools for effectively and deeply infusing pedagogy and instruction inside digital games. After presenting an overview of the state of the art of the SG taxonomies, the paper introduces the pedagogical theories and models most relevant to SGs and their implications on SG design. We also present a schema for a proper integration of games in education, supporting different goals in different steps of a formal education process. By analyzing a set of well-established SGs and formats, the paper presents the main mechanics and models that are being used in SG designs, with a particular focus on assessment, feedback and learning analytics. An overview of tools and models for SG design is also presented. Finally, based on the performed analysis, indications for future research in the field are provided.

1. Introduction

Serious Games (SGs) - games designed for a primary goal different from pure entertainment [1], [2], [3], [4] - are receiving a growing interest for education. Exploiting the latest simulation and visualization technologies, SGs are able to contextualize the player's experience in challenging, realistic environments, supporting situated cognition [5]. Play supports players in exercising freedom that can complement formal learning by encouraging learners to explore various situations [6], with limited barriers of space and time. Cost is another key factor, especially for SGs providing simulation of complex/costly environments [7] and of dangerous/critical situations [8].

SGs can be multiplayer, favoring team-building and collaboration/cooperation in facing challenges and issues [9], [10], [11]. The widespread diffusion of mobile gaming is opening further perspectives also for learning and online socialization (e.g., [12]; [13]). Furthermore, a large and growing population is increasingly familiar with playing games. SGs do not target exclusively power-gamers (typically young males fond of First Person 3D immersive experiences). Power-gamers represent just 11% of the gaming community, while other types of players (e.g., social, leisure, occasional) are increasing in number. This audience enlargement has been enabled by new typologies of games (e.g. brain training games, intellectual challenges such as Professor Layton and the Curious Village and Phoenix Wright: Ace Attorney) and by new modalities of interactions (e.g. online collaboration, verbal commands, gesture-based control, social environments, family gaming). Moreover, several new games (e.g. mobile, some consoles and new interaction modalities) are inexpensive to produce and run on low-cost computational platforms. Figure 1 provides a set of screenshots from state of the art SGs.

Business data argue for a favorable trend for SGs. IDATE (2012) estimates the current global market of SGs at 2.35bn €, with steady growth and huge potential. Positive trends for SGs and gamification (which includes the use of SGs) are also provided by other market and expert analysis and surveys [14], [15], [16]. Performing a survey with e-learning professionals and experts, and comparing outcomes with literature review, [17] stresses a "positive view", as SGs are perceived as "de facto effective learning environments [18] because games challenge and support players to approach, explore and overcome problems".

Fig. 1 – Snapshots from state of the art sample serious games. Clockwise from top left: the Siege of Syracuse, RescueSim, Simport, Building Detroit.

Use of SGs for education and training involves also some concerns. [19] argues that intended learning outcomes and game objectives and features (e.g., difficulty level, duration, aesthetic, and interaction modalities) might conflict among each other. The 'suspension of disbelief', typically happening in a game, may negatively influence the learning processes. Certain socio-demographic groups may feel excluded and frustration may be created by usability issues and competition. There is a risk of stressing extrinsic motivation towards an educational topic (through competition, rewards, badges, etc.), with respect to intrinsic motivation, that is fundamental in the long-term. Developing triple A commercial games is extremely expensive, and SGs cannot afford such budgets. Thus, the term "game" may create excessive expectations in the users. Moreover, a study by Jayshiro Tashiro reports that while there is insufficient evidence to know if current serious games may improve healthcare education, there is evidence that they may inculcate inadequate clinical pattern recognition. All these observations highlight the fact that SG design is a complex challenge, involving a variety of dimensions, and that use of SGs in educational settings should be properly organized.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of the SG history, application domains and taxonomies. Section 3 sketches the main disciplines involved by SG development, while section 4 goes in detail on the underlying pedagogical theories and models and their implications for SG design. Section 5 addresses the deployment and use of SGs. Section 6 presents a set of sample SGs, in order to highlight typical SG mechanics and models. Section 7 goes in detail about three main SG-specific aspects: assessment, feedback and learning analytics. An overview of tools and models for SG design is provided in section 8. Section 9 draws the conclusions.

2. History, application domains and taxonomies

Following from the Platonic differentiation between games for fun and games for learning, the term "serious game" was firstly used by Abt (1970). The "serious game" term in a digital context was firstly used in 2002, with the start of the Serious Game Initiative lead by David Rejeski and Ben Sawyer in the US.

SGs were initially conceived to train people for tasks in particular jobs, such as training army personnel [20] (Fig. 2 shows a couple of screenshots from the famous America's Army), or salesmen. The games typically concerned acquisition of knowledge and/or procedural skills and were targeted at a captive audience. With the diffusion of "non-hard" gaming and of new devices (e.g. smartphones, tablets, various types of consoles), a variety of SGs has been rapidly established, for different types of users (students, adults, workers, etc.), applications/goals (instruction, training, advertising, politics, etc.) and implementing different genres (arcade, first person shooter, etc.). [6] discuss a number of examples of learning games, showing that uses of SGs now "span everything from advancing social causes to promoting better health to marketing. […] Advergaming is a popular form of advertisement that delivers commercial messages through games".

Fig. 2 – Snapshots from America's Army, one of the first SGs, still used for recruitment

Work on SG categorization clearly shows such a variety. Several taxonomies have been proposed in literature that classifies SGs according to different criteria, such as application domains [3], markets [21], skills [22], [23], learning outcomes [24]. The classification proposed by [25] that rapidly became a reference, proposed a matrix of two major criteria: market (the application domain) and purpose (initial purpose of the designer). Items in the first dimension include: government, defense, marketing, education, corporate, etc. Items in the second dimension include: advergames, games for health, games at work, etc.

[26] introduce categories based on the psycho-pedagogical and technical level of games. A hypercube taxonomy has been developed by [27], highlighting the following dimensions:

- Purpose – ranging from fun/enjoyment to training/learning
- Reality – ranging from imitation of real and fictitious contexts to proving abstract visualizations such as in games like Tetris.
- Social Involvement – ranging from single player games to massively multiplayer games.
- Activity - ranging from active game types (e.g., action games or – even with a physical dimension – the Nintendo Wii game play) to passive game types (where at the end of this continuum the passive perception of a movie is situated).

serious.gameclassification.com (2880 featured games, as of January 2014) is a collaborative classification of SGs, which is a reference at world level [28], [29]. The selected classification dimensions - that are a clear extension of the [25] model - are:

- Gameplay (game-based vs. play-based – games have fixed goals to achieve; core rules represented by bricks constituting a game)
- Purpose (Education, information, marketing, subjective message broadcast, training, goods trading, storytelling)
- Market (Entertainment, State&Government, Military &Defense, Healthcare, Education, Corporate, Religion, Culture&Art, Ecology, Politics, Humanitarian &Caritative, Media, Advert, Scientific Research)
- Audience (Type: General Public, Professionals, Students; age groups)

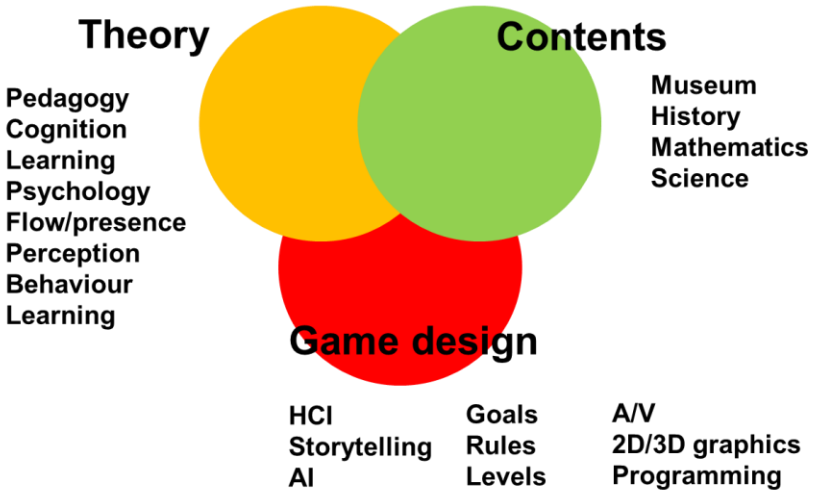
More structured databases of educational SGs have been built in projects such as Imagine1, Engage learning2, and GaLA3/Serious Games Society (SGS)4. The GaLA SG Knowledge Management System5 includes a number of descriptors that are useful for conducting SG studies, including:

- Description/classification (genre, platform(s), application domain, learning curve, effective learning time, play mode, player assessment, provision of feedback, etc.)
- Analysis of game components (UI, rules, goals, entity manipulation, assessment), for a detailed specification of the game mechanisms.
- Pedagogy. The GaLA taxonomy is organized in two major sectors: 1) Theoretical frameworks: constructivism, objectivism, personalism, etc. and 2) Outcomes: cognitive [30]; psycho-motorial [31]; affective [32]; Soft-skills [33].
- Deployment ("Use of the game"), specifying settings such as: target users (age, specific categories of persons, school level, etc.); target topics; prerequisites for use (if any) (cognitive, content-related, domain related, psychomotor, etc.); context of use (e.g., formal education, corporate training and other)
- Technologies employed for the development. Game engine, development tools/platforms, AI algorithms.

Metrics are also provided to allow an assessment of SGs by experts along dimensions such as learning effectiveness, efficiency, fun level, etc.

3. SG development, a multidisciplinary challenge

In order to develop and deploy effective tools for learning, it is necessary to consider all the stakeholders (users, educators, families, researchers, developers/industries) and the whole cycle from research to market and vice-versa. From a scientific point of view, this needs considering a complex mix of disciplines and technologies, such as: Artificial Intelligence (AI), Human-Computer Interaction (HCI), networking, computer graphics and architecture, signal processing, web-distributed computing, neurosciences. These technologies are to be developed and exploited in a target-oriented multidisciplinary approach that puts the user benefits at the centre of the process. Given the instructional goal, SGs should provide quality contents on the target domain and their development should be strongly grounded in proper educational foundations [34].



[1] www.imaginegames.eu
[2] www.engagelearning.eu
[3] www.galanoe.eu
[4] www.seriousgamessociety.org
[5] http://studies.seriousgamessociety.org/

Fig. 3 – The three kernels of SG design

Figure 3 sketches the complexity of the various disciplines and factors involved in proper SG development. In the reminder of this article we discuss more in depth some of the most important topics.

4. Pedagogical theories and models and their implications for SG design

Games are "per se" motivating – and can be successfully employed with this aim. However, instructional effectiveness involves other aspects that can be analyzed at the light of the pedagogical theories. The goal of this section is not to provide an overview of such theories, but to present and discuss the main aspects involved in SG design and their implications.

The design and use of digital serious games has a certain theoretical foundation in the constructivist learning theories, that stress that knowledge is created through experience while exploring the world and performing activities (e.g., [35]; [36], [37]. Implications on game design involve the creation of virtual environments, typically 3D, where the player can gain knowledge through exploration and by practice (e.g., manipulating objects), possibly in collaboration with other people.

Constructivism stresses the importance of the learner to build his own knowledge. However, [38] argues for the importance of guidance, in particular for novices. They refer to the cognitive load theory (CLT) [39], stressing the need of explicit teaching because of the limitations of the working memory. Analyzing user experience of Crystal Island, [40] reports that "high-achieving science students tended to demonstrate greater problem-solving efficiency, reported higher levels of interest and presence in the narrative environment, and demonstrated an increased focus on information gathering and information organization gameplay activities". However, "lower-achieving microbiology students gravitated toward novel gameplay elements, such as conversations with non-player characters and the use of laboratory testing equipment". Observing the gameplay, the authors noticed that "high-achieving students tended to utilize more traditional science resources such as textbooks and worksheets while attempting to solve the presented mystery. In contrast, low-achieving students employed the help of expert nonplayer characters and virtual lab equipment to aid in their quest". These observations seem to stress the fact that learning is a complex activity that requires graduality and needs several steps, that have to be supported by various tools (e.g., paper and digital, reading and writing, etc.) and generally have to be guided, possibly by a real adult, in order to be meaningful/compelling for the learner and not to waste time and energies. Maps, landmarks, contextualized helps, objectives' lists with status information are game elements that could be employed in order to support avoidance of player's cognitive overloading.

Another important theory is flow, based on Csikszentmihalyi's foundational concepts [41]. Flow was first employed to measure engagement in an educational game in [42]. [43] drew together various heuristics present in the literature into a concise model, the GameFlow, consisting of eight elements: concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. As the result of more than three decades of commercial competition, most of today's video games deliberately include and leverage the eight components of Flow [44]

[45] highlights that most games adequately meet two primary elements of flow - clear goal and feedback - but the balancing of game challenges and player skills is often lacking. In order to maintain a user's Flow experience, the game's activity must balance the inherent challenge and the player's ability to address and overcome it [44]. If the challenge is beyond that ability, the activity becomes so overwhelming that it generates anxiety. On the other hand, if the challenge fails to engage the player, the player loses interest and quickly tends to get bored. However, designing such a balance becomes a greater challenge as the size of the potential audience grows, which is the typical case of video games. Most games presently offer only a single narrow, static experience, which might keep the typical player in the Flow but may not be fun for the hardcore or the novice player. Several choice possibilities should be given to the player, adapting to different users' personal Flow Zones [44], which is costly and may interrupt the user's experience. The best way for designers to avoid these counterproductive situations is to embed the player choices into the core activities of the interactive experience [44] and/or to make the game automatically adaptive [46] in particular through player state assessment [47]. A consequent research issue is how to measure the player flow status during the game, possibly with no invasiveness, for instance through neuro-physiological signal processing [48]. In fact, using questionnaires (either on paper or electronic) requires interrupting the game and leads to variable subjective values. Moreover, participants may report their belief in general, but may not reflect the experiences of the moment while playing [49].

Personalism tends to consider education as a human relationship between a child (learner) and an adult (teacher) who introduces to reality [50]. Centrality of the person stresses user-centered design (e.g., 51). Other specific implications for SG design may involve: presence of real-world hooks (e.g., territorial gaming – [51]) and references inside the game, possibility of supporting a dialogue between learner and teacher, game analytics able to provide detailed information about the player's performance that could be analyzed by the teacher in order to advise on possible improvements and corrective actions.

Several learning models have been employed to inspire SG design and assess validity of SGs. Among the knowledge models, we highlight the Nonaka SECI model [52], which is mentioned as a theoretical basis for the use of SG-based workshops, at least in the fields of business, management and manufacturing [53], and the Kirkpatrick's "Four Levels of Learning Evaluation", which is a popular learning impact assessment model, involving the following levels: reaction, learning, behavior, results [54]. A fifth level of evaluation has been added in new versions of the model by [52] and by [5], considering also return on investment and impact on clients and society, respectively.

Two pedagogical models look complementary, simple and particularly useful to analyze SGs [55]: the Revised Bloom Taxonomy [30], which is the most popular cognitive approach to SG evaluation [37] (Fig. 4); and the Kolb's Experiential Learning model [52] (Fig. 4), which systemizes the work rooted on Piaget's cognitive developmental genetic epistemology [57], on Dewey's philosophical pragmatism [35], and on Lewin's social psychology, putting the experience at the centre of the learning process. Good SGs and simulations should allow users to make significant experiences, thus typically supporting the experiential learning pedagogical paradigm.

Cognitive competences in the Bloom taxonomy (Bloom, 1956)	Learning goals in the Revised Bloom taxonomy (Anderson and Krathwhol, 2001)
Knowledge	Remembering
Comprehension	Understanding
Application	Applying
Analysis	Analysing
Synthesis	Evaluating
Evaluation	Creating

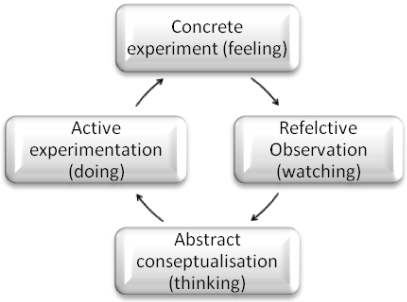


Fig. 4 - The Revised Bloom taxonomy and the Kolb's learning stages

5. Deploying and using SGs

SGs are being used in a variety of training and educational settings ranging from elementary schools (e.g., with games for mathematic and foreign languages) to universities (e.g., in particular with games for business management, logistic and manufacturing, e.g., [58]). Fig. 5 provides two sample screenshots of such SGs. Extrensively gamified courses are also being experimented [59]. Even the use of Commercial Off The Shelf (COTS) games (e.g., Civilization, SimCity) is being considered for instruction, given their popularity, validity and cost-effectiveness. COTS are not tailored to specific instructional goals, but can be modded, allowing a flexible use in education.

Fig. 5 – Hands-On Equations 1 Lite, for math instruction, and Renault Academy, for training salesmen and dealers

When using commercial games or SGs, typical choice criteria include the following [59]:

- Ability to cover the needed topics for the target students (that usually feature different profiles)
- Satisfaction of basic pedagogical principles
- Satisfaction of basic usability criteria
- License costs
- Possibility for students to play at home or, anyway, on their laptops

From a methodological point of view, in order to describe and analyze the educational characteristics of each game, which is a fundamental step for the selection, [55] report their positive experience using the Revised Bloom Taxonomy and of the Kolb's learning stages. They also propose a schema for a proper integration of games in education, supporting different goals in different steps of a formal education process, as shown in Tab. 1. While based on experience in business games, the authors argue that the schema could be employed also to other subjects.

Table 1. Fitness of games to the different steps of an educational process

Educational process' step	Fitness of games
Initial motivation.	Games look very useful for raising awareness and interest of a student about a new topic
Theory	Here the role of the teacher and of tools like books look quite effective and efficient, especially to support abstraction
Practice	Games look very useful for practicing learned contents. Games should be of various levels, allowing different degrees of freedom according to the student expertise. Supervision of the teacher is highly recommended in order to avoid misconceptions and loss of coordinates that could easily arise in a complex simulation environment
Verification	Games could be useful to verify some aspects of knowledge/skill acquisition, but attention should be paid to avoid over-fitting on the game mechanics. In general, use of digital games is particularly suited for tracking the user and understanding his performance under some measurable dimensions, through learning analytics

Concerns have emerged about an extensive use of videogames, in particular by the youngsters. This is to be kept in consideration also in the case of educational games, in particular when considering hyper-stimulation and distinction between virtuality and reality. This point on the one hand stresses again the necessity of responsible adults able to manage the education process and the other hand the importance of user-centered design, considering all the process stakeholders, starting from the parents.

6. SG mechanics and models through examples

This section intends showing the main mechanics and models that are used in SG designs, by analyzing a set of well-established SGs and formats.

CancerSpace (Fig. 6) is a game format that incorporates aspects of e-learning, adult-learning theory, and behaviorism theory to support learning, promote knowledge retention, and encourage behavior change [60]. CancerSpace's design encourages self-directed learning by presenting the players with real-world situations about which they must make decisions similar to those they would make in clinics. The targeted users are professionals working in community health centers. The authors stress the main peculiarities of the game with respect to a mere collaborative 3D e-learning environment. The first point is about role-playing: the user has to help the clinical staff evaluate the clinical literature, integrate the evidence into their clinical decision-making, plan changes to cancer-screening delivery, and accrue points correlating to increased cancer-screening rates. The user takes decisions and observes whether the chosen course of action improves the cancer screening rates.

The game includes a small number (four) of patient-provider interactions in which the decider must talk with a patient reluctant to get screened, try to educate that patient, and hopefully get him or her screened. The Decider must negotiate cultural and language barriers as well as the patient's changing attitudes toward screening. The player's conversation choices are evaluated in preprogrammed decision trees, leading to success (the patient decides to get screened) or failure.

Chance is considered an important entertainment and variability feature. To this end, wildcards are implemented, that reflect certain unplanned events common to community health centers such as a budget cut, funding of a grant, or a staff member transferring to another clinic.

Other critical factors for CancerSpace concern the use of audio elements such as buzzers, chimes, and other sound effects, combined with video elements such as quick animations indicating an incorrect answer and a mentor character showing emotions ranging from strong disapproval to strong approval.

To stimulate gameplay, CancerSpace has adapted an award system that motivates players to increase screening rates. The CancerSpace scenarios in which the decider guides the virtual clinical staff are based on research-tested interventions and best practices. Users receive points on the basis of their performance. At each game's conclusion, a summary screen indicates which decisions the player implemented and their effect on the clinic's screening rate.

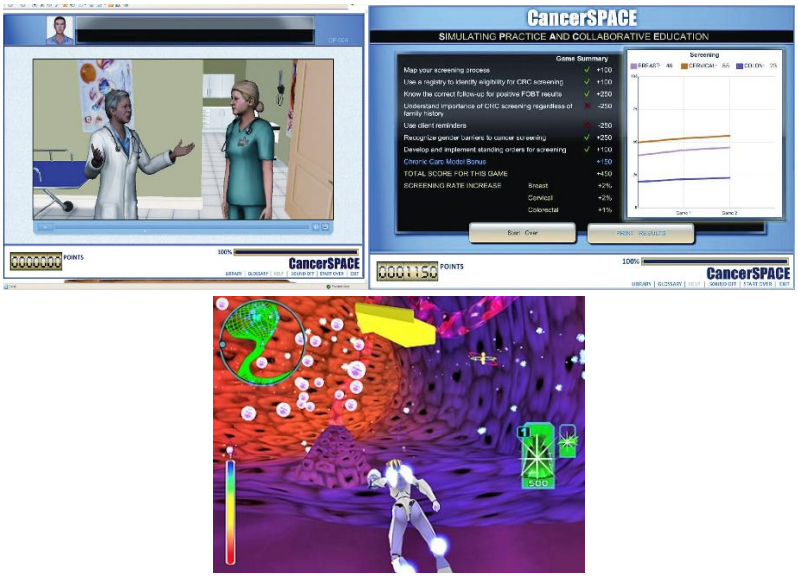


Fig. 6 - Snapshots from CancerSpace and ReMission

Re-Mission 2 (Fig. 6) is a collection of online games that help young people with cancer fight their disease. Each game puts players inside the human body to defeat cancer, using weapons like chemotherapy, antibiotics and the body's natural defenses. The games are designed to motivate players to stick to their treatments by boosting self-efficacy and positive emotions and by shifting attitudes about chemotherapy. A study results show that neural circuits implicated in reward (i.e., caudate, putamen, and nucleus accumbens) activated strongly while players were actively playing Re-Mission but not when other players passively observed the same gameplay events. This reward-related activation is associated with a shift in attitudes and emotions that has helped boost players' adherence to prescribed chemotherapy and antibiotic treatments [61].

SGs and Virtual World technologies allow the creation of realistic 3D environments, with full sensory representation and immersion. These environments, populated by players' avatars and by Virtual Human Characters (VHCs) controlled by the computer's Artificial Intelligence (AI). This is the concept of Living Worlds (LWs). In their LW for cultural training in Afghanistan, [62] indicate several mechanics. First, the main objective: the player wins by successfully interpreting the environment and achieving the desired living-world attitude toward him. The entire living-world game space is fueled by the knowledge-engineering process that translates the essential elements of the culture into programmable behaviors and artifacts. For instance, "In Afghan culture, older men have great influence over younger men, women, and children through local traditions and Islamic law". "Ideologically, the guiding principles of Afghan culture are a sense of familial and tribal honor, gender segregation, and indirect communication". All the

non player characters (NPCs) in the game are modeled accordingly. These models control activities ranging from gossiping to daily behavior such as traffic/errands. The overall social environment is modeled as well (e.g., simulating generation of factions and shuras). Winning in the game "simply" requires successfully navigating cultural moves in the game space thus achieving a good overall attitude of the village toward the player.

NPCs are highly realistic both in their aspect and in their movements. Sound is designed keeping into account three dimensions: global (e.g., weather conditions and distance traffic), regional (e.g., a radio in the room) and local (e.g., footsteps, voices).

Another key aspect is assessment, through the underlying 3D Asymmetric Domain Analysis and Training (ADAT) model that allows for analysis of the cultural behavior exhibited by the player in the game. Conversations and interactions between the NPCs and the player are recorded through a text log to provide game performance analysis. The assessment tool lists all possible choices for player behavior and conversation, highlighting both the player's choice and the most culturally appropriate response. The tool provides scores on the opinion of the player at the NPC, faction, and village level. Additional comments can be provided that highlight the player's weaknesses, explaining why a particular response is most appropriate. Feedback is thus provided to improve future performance.

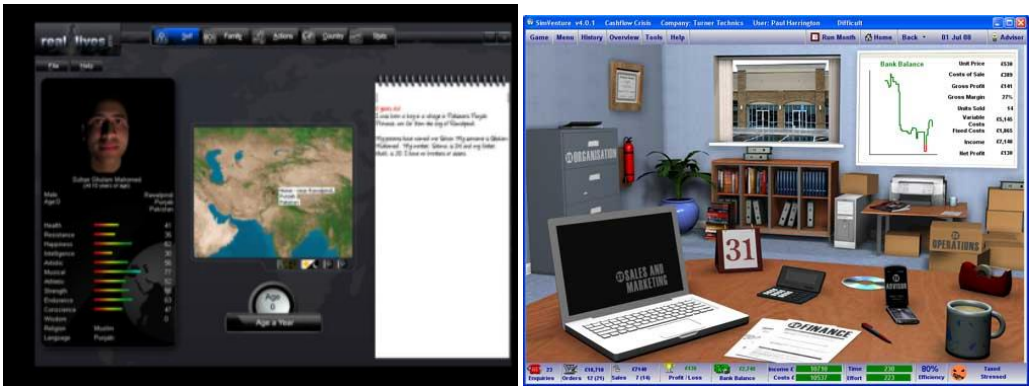


Fig. 7 - Snapshots from Real Lives 2010 and SimVenture

Real Lives 2010 (Fig. 7) is an interactive life simulation game that enables you to live one of billions of lives in any country in the world. Through statistically accurate events, Real Lives brings to life different cultures, human geography, political systems, economic opportunities, personal decisions, health issues, family issues, schooling, jobs, religions, geography, war, peace. Compared with a control group, students who played the simulation game as part of their curriculum expressed more global empathy and greater interest in learning about other countries [63].

Managerial business SGs like SimVenture (Fig. 7), GoVenture CEO and MarketPlace are increasingly being used in higher education [59]. They represent detailed business simulations where users (also grouped in teams) are responsible for managing a company in various market scenarios. A number of performance indicators (e.g., Bank Balance, cash-flow, Company Value, Gross Profit), that are useful for self-assessment, are provided, but it is generally difficult for the player to understand the impact of his choices (e.g. about marketing, personnel, etc.) on those figures. CEO provides a simulation management module through which the teacher can configure different types of inter-team team competition scenarios. [55] highlight that, in this kind of games, the cyclical nature of the game play (simulated business monthly periods of the player's company) can be directly mapped to the sequential steps described by Kolb, such as: experience of the simulation's business scenarios; observation of the player company's results in the simulated month; conceptualization, in order for the player to understand the situation and the decisions to be taken for the next periods; experimentation, through the choice of the parameter values for the next period.

Describing lessons learnt about what makes games useful from a therapeutic point of view, [2] - they designed and user tested stroke rehabilitation games - highlight the importance of the following attributes: ensure playability for a broad range of patients: multimodal input, provide examples, direct and natural mappings; ensure games are valuable from a therapeutic perspective: ensure that users' motions cover their full range, detect compensatory motion, allow coordinated motions, let therapists determine difficulty; ensure that games fun and challenging: audio and visuals are important, automatic

difficulty adjustments provide adequate challenge, NPCs and storylines are intriguing. Future steps concern creation of connections with friends and family members, and support of socialization.

Another key aspect for gaming and learning is online collaboration that can involve learners and educators as well [9]. Collaboration is a key skill for current jobs and practicing collaboration in concrete simulation tasks is expected to be highly beneficial (e.g., [64]). While some SGs support collaboration in order to achieve their goal (e.g., [65]), others, like The Barn's TeamUp [66] or Escape from Wilson Island [11], are ad-hoc designed with the main target of fostering collaboration and leadership.

[67] abstracted a conceptual model – the SandBox Serious Game - which relies on a generalization of task-based learning theory. The model invites players to perform cognitive tasks contextually while exploring information-rich virtual environments. The model defines games (e.g., treasure hunts) that are set in realistic virtual worlds (typically 3D) enriched with embedded educational tasks, which have been implemented as minigames that can be instantiated out of a set of predefined templates. This approach simplifies the authoring work, allowing an approach similar to the mind-maps concept. Tasks/minigames (played through a virtual smartphone interface, Fig. 8) allow the player to focus on a specific item/topic in the environment. Each task/minigame involves very short introduction and conclusion texts that complement and reinforce the task experience through plain verbal knowledge. Discussing a lab user test aimed at verifying the acquisition of cultural heritage knowledge, the authors report that games appear particularly suited for supporting the study of images, especially of iconography. Compared to reading text, a game forces the player to focus more strongly on problems, which favors knowledge acquisition and retention. Learning complex concepts requires an investigative attitude, which can be spurred by well-designed games. Good design involves usability, graphic appeal, appropriate content, and the presence of connections which a player must discover in the content. Players should be asked to pay attention to and reason about their whole game activity - including the relationships between the game content, the brief introduction, and concluding texts.

Fig. 8 - Snapshots from the Travel in Europe sandbox SG prototype

When designing a SG, definition of levels is a major aspect. In general, novice learners/users need guidance, while advanced users take benefit from experimentation. Thus, as a general rule, we suggest that the lower levels are rich of game elements, that drive the user along an instructional path, while higher levels are more simulation-like, where the player can exercise freedom exploring a field for which he has already developed some reliable knowledge structures.

7. Assessment, feedback and learning analytics

An effective application of SGs for education and training particularly demands appropriate metrics, analytics, tools, and techniques for in-game user assessment [68], [69], [70]. Assessment is a key for games and education, since it allows knowing and understanding the actual end-user condition, which is the basis for an appropriate treatment. Proper assessment [71] requires continuously tracking the user in all its game activities [72], allowing appropriate feedback and also supporting adaptivity and personalization [73]. Assessment should be done in real-time and without interrupting the user's flow (stealth or embedded assessment) [74], [71]. This can be achieved in particular by measuring elements such as learning outcomes and engagement, considering the twofold nature of SGs as compelling games that achieve precise educational goals (e.g., [69], [70].). Learning analytics [75], [76] and game analytics [77] are the tools now being developed in order to improve game design and to provide feedback to the player based on the actual gameplay data.

Adaptivity to different learner profiles is a capability that is difficult to provide by human teachers in large students classes, thus represents a significant added value for a system able to support efficient learning and teaching.

Devices such as stereo cameras, eye trackers, tablets and smartphones, pointing devices, motion sensors, sensors related to the central and peripheral nervous systems (e.g., galvanic skin response, heart rate, neuronal activity) [48], amongst others, present opportunities to develop innovative solutions for continuous user monitoring and assessment.

However, due to the complexity of human nature and individual differences, an objective and systematic assessment of learner behavior and performance remains highly difficult. In addition, data analyses and evaluation methods keeping into account the very nature of SGs are still under-developed [70].

8. Tools and models for SG design

A variety of tools - ranging from photo editors to game engines, from 3D editors and renderers to visual programming environments - are being used for SG design and development. Selection of the tools to use mostly depends on the game genre and the target user device. Diffusion of the Unity 3D game engine has signed a strong innovation, allowing easy and efficient development of games, at low cost, also by people with limited programming skills and knowledge. Other widely spread tools include the Unreal engine and, particularly for developing 2D games, HTML 5 and Adobe Flash.

SimVentive has developed a toolkit to support SG development by letting designers create smart objects and define how they respond to events, states and the passage of time exploiting a set of intelligent agents. eAdventure is a platform that is being used to facilitate integration of educational games and game-like simulations in educational processes and Virtual Learning Environments (VLE) [78]. Thinking Worlds is a free tool for rapid creation and publishing of 3D sims and games. An interesting and detailed classification of game development tools is maintained online at http://createtools.gameclassification.com. Specifically in the field of SGs, GenCSG (Generic Case Study Game) is an authoring framework that enables teachers with no programming skills to create SGs supporting the “case method”, with very simple graphics and adapt them to their specific teaching situations [68]. The “case method”, which is used in many domains and is relevant for several pedagogical theories, consists in presenting the learner with a problem (the case), inspired by a real situation, and putting him in the position of the decision maker [79]

Despite the abundance of literature on SGs, few papers provide a detailed description of the specific SG mechanics (and underlying methodologies) through which a topic can be “translated” into a SG. Still, “many educational games do not properly translate knowledge, facts, and lessons into the language of games. This results in games that are often neither engaging nor educational” [70]. [80] have proposed the Learning Mechanics-Game Mechanics (LM-GM) model, which supports SG analysis and design by allowing reflection on the various pedagogical and game elements in a SG. The LM-GM model includes a set of pre-defined game mechanics and pedagogical elements that have been abstracted from literature on game studies and learning theories.

9. Conclusions

SGs aim at improving learning processes by providing attractive, motivating and effective tools that may also create positive situations among students and with teachers. So far, effectiveness of SGs has been shown by recent studies (e.g., [81]; [82]), but the potential of SGs for instruction – in particular providing compelling plots and contexts where players can effectively and efficiently acquire new knowledge/skills and where progress can be accurately verified - is still far from being fulfilled. There is a growing need for scientific and engineering methods and tools for efficiently building games as means that provide effective learning experiences (e.g., [34]; [67]; [68]). This will allow covering a variety of topics with new tools that could help students that have difficulty with other instructional approaches. Development of new generation SGs requires exploitation of advanced technologies (in fields such as Artificial Intelligence, Human-Computer Interaction, modeling and simulation, neurosciences, virtual reality, etc.,) and accurate studies on the design of game formats, mechanics and dynamics, that are able to effectively join educational and entertainment goals - a very difficult balance to achieve - in meaningful and compelling wholes.

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