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Games, Simulations, Immersive Environments and Emerging Technologies

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Synonyms

Game-based Learning; Serious Game; Advanced Computer Human Interactions, Virtual and Mixed Reality

Introduction

This entry presents an overview of advanced technologies to support teaching and learning. The use of innovative interactive systems for education has never been higher. Far from being just a trend, the objective is to use the current technology to cover educational needs and create relevant pedagogical situations. The arguments in their favor are generally their positive effects on learners' motivation and the necessity to provide learning methods adapted to our growing digital culture. The new learning technologies and emerging trends are first reviewed hereunder. We thus define and discuss learning games, gamification, simulation, immersive environments and other emerging technologies. Then, the current limits and remaining scientific challenges are highlighted.

Learning Games

The use of games in education is not a novelty. Humans have always used games to teach young people. However, children growing up, education becomes less and less fun. The Serious Game approach changes this trend by arguing that the game remains a pedagogical means that can be useful at any age.

The term Serious Game can be used to cover a wide variety of systems. In its broadest definition, Serious Games are games used for purposes other than mere entertainment (Susi, Johannesson & Backlund, 2007). The serious intention can be educational, informational, commercial or ideological for instance. When the main goal is to favor knowledge learning or competencies building, the term used is Learning Game. These games can be computer supported or not. Thus, Learning Games can be played using cards and other materials (board games) or using computers, tablets or smartphones (digital games).

The main benefit of game-based learning is the user's motivation linked to the inherent goals of the game whose fulfillment is a source of satisfaction and rewards. So the game goals motivate the player's actions. Moreover, above all, a game has the specificity of being different from the real world, players being able to act without fearing the consequences of their actions. Users can try and immediately see the impact of choices. According to the feedback, players can learn and develop abilities. The main educational approach is therefore active learning, the game allows the learner to decide and act within a set of game rules. For example, in the Learning Game *Refraction*, learners have to split a laser into several beams in order to redirect fractions of the original full-strength laser to power spaceships (Fig. 1). This puzzle game helps students to learn and apply the concepts of basic fraction manipulation in mathematics.

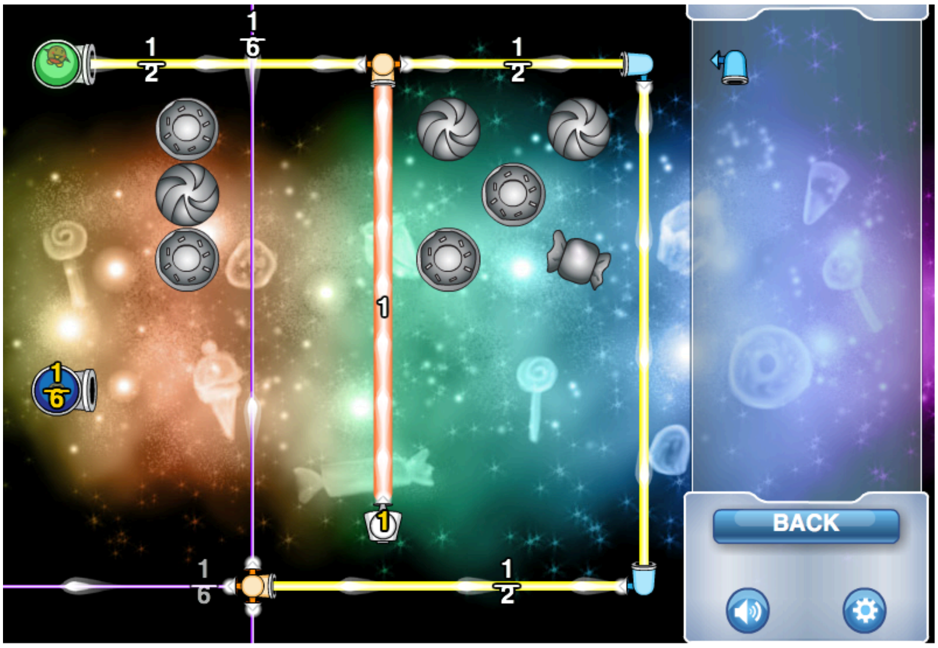

Fig. 1 Refraction: a puzzle game to learn fractions (source: centerforgamescience.org)

With games, learning occurs through interactions with objects, places and other people (collaborative learning). Finally, emotion is another important pedagogical factor. The universe and the narration of the game contribute to engage learners by making them feel emotions. Game-based learning is definitely a powerful means to take into account the game and digital culture of the new generation of learners, characterized by a relatively short attention span and a preference for exploration and discovery.

The educational purpose of a Learning Game can also be achieved through a debriefing. Often conducted with a teacher, debriefing sessions allow to get out of the game and facilitate the transfer of skills to other situations. The role of the teacher is also considered to be important to animate the game situations and to monitor the learners.

Actually, a wide variety of learning games can be found. For instance, location-based games are played on mobile devices and are useful to promote situated learning. Educational Alternate Reality Games (ARG) are based on transmedia storytelling to propose a social experience to learners who need to collaborate to accomplish activities and solve problems. In this kind of games, learners are asked to coordinate real-life activities (finding objects, talking to characters, …) and online activities (watching video, responding to emails, …). As another example, Epistemic Games make it possible for leaners to learn to think in innovative ways by playing the role of professionals while learning knowledge and abilities they apply in the game (Shaffer, 2006).

Nevertheless, most educators and teachers have not been trained in the pedagogy of gaming. The use of games in the classroom implies a new paradigm for the student-teacher relationship and raises many technological questions that most teachers are not ready to face. In any case, the support of school technical staff is crucial for the installation and running of the games.

From the point of view of the creation of learning games, inevitable technical issues are raised. The development of the game must ensure that the proposed interactions are in line with teaching expectations. So teachers need to be part of the design team. Another approach exists with the provision of authoring tools that allow teachers to create learning game without coding. This possibility is detailed later in the part dealing with research questions.

Gamification

Turning a learning environment into a serious game requires a complete redesign, which is very expensive and time consuming. An easier solution is to gamify a course by adding game design elements. In a general way, gamification consists in using game components in non-game contexts. This approach is used in various domains such as marketing, health, architecture and crowdsourcing. In education, gamification relies on game design features embedded in a learning situation to foster student motivation (Deterding *et al.*, 2011). The most common game elements are: points, badges (trophies symbolizing a task fulfillment), leaderboards, object collection, … A good example of gamification is *Classcraft*, a platform to gamify classrooms (Fig. 2). With *Classcraft*, teachers and students play together in the classroom a role-playing game. Students can level up, work in teams, and earn powers that have real-world consequences (e.g. switch seats, choose the order during presentations, …).

Fig. 2 Classcraft, a platform to gamify classroom activities (source classcraft.com)

The Learning Management Systems (LMS) propose more and more often gamification features. For instance, some plugins can be integrated to Moodle to gamify courses: badges, achievements, points, … Some other platforms even build gamification into the bones of their learning solutions (i.e. The Academy LMS, Paradiso LMS, …). In any case, these systems require time from the teachers to set up the game features they want to set up for their students.

Simulation

Simulations should be distinguished from Serious Games. A game can be based on a simulator, but this is not necessarily the case. Digital simulations are based on virtual environments that replicate, with a high degree of fidelity, real-life phenomena or situations. For instance, simulators in STEM fields (science, technology, engineering, and mathematics) rely on specific models and equations (electronics, physics, …) to calculate results with a given set of input data. A simulator gives the opportunity to carry out experiments by modifying inputs and observing the outputs generated by the system. For example, with *Newton*, users can manipulate 3D virtual objects and investigate real-life physics experiments interactively (Fig.).

Even if simulations cannot replace practical learning with real devices, they offer the possibility to train without costly materials and avoiding potential dangers. Simulators can also be used in non-STEM fields to represent a global behavior or situation. For example, simulators exist to train people to apply procedures or to use the right sales method in front of customers.

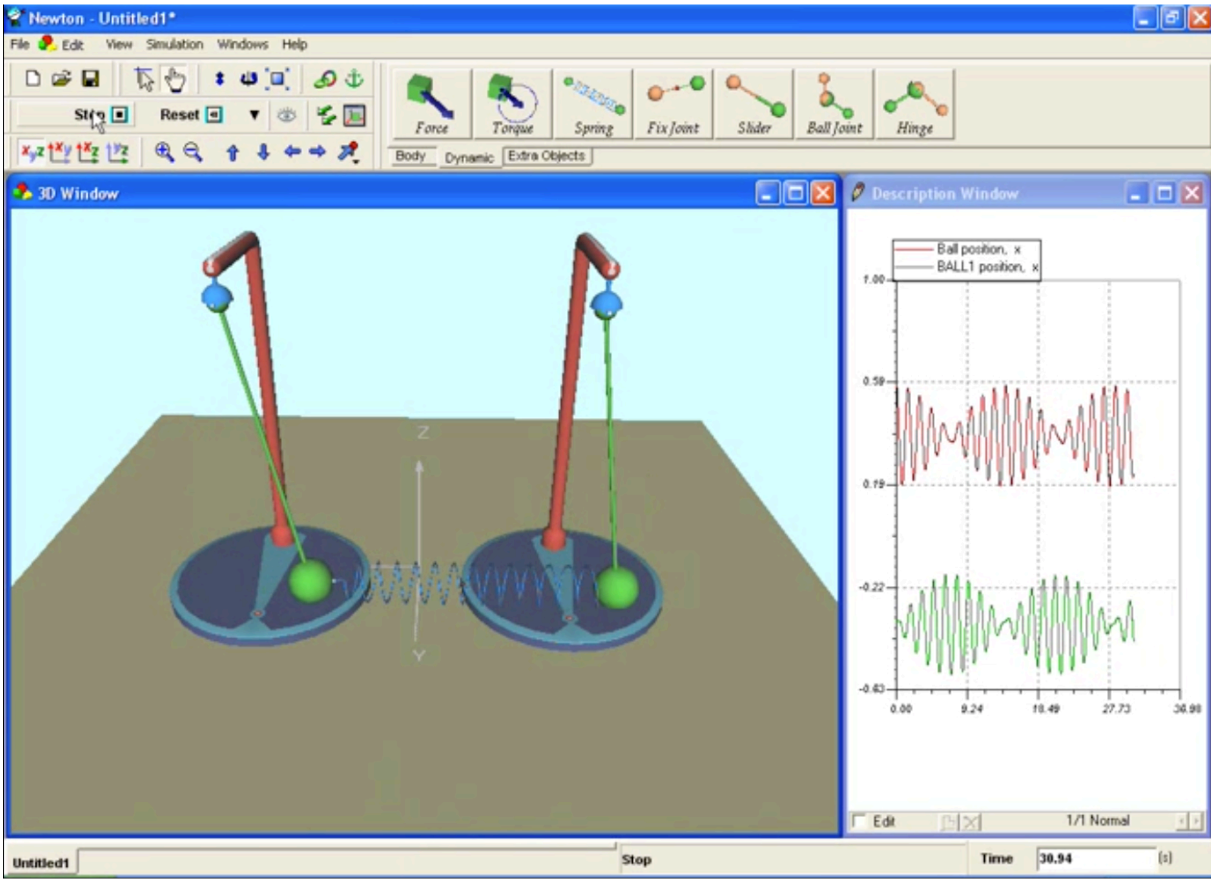

Fig. 3 Newton: a simulation environment to manipulate and investigate real-life 3D physics experiments interactively (source newtonlab.com)

As said before, some Serious Games integrate a simulator, i.e. a model of a real-world phenomenon (in mechanics, physics, economics, …). For instance, *Physica* is an example of serious game based on a physical simulator. In this case of simulation-based serious game, a scenario is designed according to pedagogical objectives to be achieved. Another example is Pulse!!, a simulation-based learning game for health care professionals which allows them to train and practice without the risk of harming patients (Fig.). Learners work in a virtual hospital where they respond to emergency situations, diagnose, and treat patients as they would in the real world. The game adds a narration to the simulator and sets goals or actions to be achieved.

Fig. 4 Pulse!! a simulation-based learning game for health care professionals (source: breakawaygames.com)

Nevertheless, the situation does not necessarily need to be realistic in a serious game: metaphorical situations can also lead learners to build skills. For instance, a fiction science scenario can help to learn concepts in sustainable energy. The skills developed can be meaningful for learners even in an imaginary situation, far from reality. There is no need to have a model to reproduce situations realistically; the game can be based on a predefined scenario.

Immersive Environments

Virtual Reality (VR) is a computer technology that uses devices and three-dimensional interfaces to simulate the user's physical presence with realistic images, sounds and other sensations. The keys elements in experiencing virtual reality are a virtual world, immersion, sensory feedback (responding to user input), and interactivity (Sherman and Craig, 2002).

Interactivity not only refers to the user interacting with the system but also to multiple users interacting together and collaborating within the same virtual space.

Several devices can be used in VR. Head mounted display (HMD), goggles with a screen in front of the eyes, are the most popular solution, and less and less expensive. More sophisticated VR systems exist, for instance CAVE (Cave Automatic Virtual Environment) are immersive virtual reality environments where projectors display multiple images on the walls/floor/ceiling of a small room (Cruz-Neira *et al.*, 1992). For the manipulation in these virtual environments, the possible devices range from simple joystick to specific data gloves or haptic feedback systems.

Compared to traditional Technology-Enhanced Learning (TEL) systems, VR environments make it possible to include the body in the learning process, and more generally to integrate sensorimotor and proprioceptive aspects, thanks to rich interaction modalities. It is thus possible to implement learning methods that immerse the learner into a given context. For example, immersive virtual environments are used for adult lifelong training in complex domains where technical systems are difficult to apprehend and human factors are critical. In I3TE (Immersive 3D Training Environment, Eon Reality), plant operators and engineers have the opportunity to train together in the same environment by reacting to a wide range of situations (Fig. 3).

Fig. 3 Training of operators in a CAVE (iCube) with the environment I3TE (source: eonreality.com)

By definition, virtual reality applications are often based on a simulation. Immersion of the learner can greatly facilitate situational learning. Nevertheless, the fact of using virtual reality is not enough to ensure learning, just as visual fidelity is not a guarantee of pedagogical effectiveness (Bossard *et al.*, 2008). A reflection must be made both on the didactic situations and on the scenario. Again, gaming scenarios can be used to motivate the player to improve skills. As discussed further, research questions remain in this field.

Emerging Technologies

In last years, devices and sensor technology evolved considerably, while costs of hardware and development platforms decreased quickly. Augmented and Mixed Reality technologies bring new opportunities for education and training. Augmented Reality (AR) overlays the real world with virtual content to create an immersive environment placing the learner in real-world context and engaging all senses (Bacca *et al.*, 2014). More generally, Mixed Reality (MR) was defined as a continuum between real world and virtual world (Milgram and Kishino, 1994). The objective is to enrich a situation based on the real wolrd or add realism in a virtual environment. This objective can be achieved using many devices such as screens, cameras, see-through glasses, mobile devices and tactile or tangible interfaces. Some research on the integration of mixed reality interactions into educational applications have highlighted their potential, mainly to improve the anchoring of learning and positioning learners in authentic situations (Egenfeldt-Nielsen, 2006). For example, the *wekit project* aims at experimenting new forms of interaction for professional training (Fig. 4). The idea consists in capturing expert experience and sharing it with trainees during task-sensitive augmented reality. A pilot study is currently conducted in the field of aircraft maintenance in order to present data in context and augment performance (Guest *et al.*, 2017).

Fig. 4 Aircraft maintenance training with the use of AR technology in the wekit project (source: wekit.eu)

Tangible User Interfaces (TUI) can also be used for advanced interactions in educational activities. With TUI, users can interact with a digital environment through physical objects. For instance, TUI can be coupled with interactive tables, taking advantage of the user ability to manipulate physical objects. Another recent trend concerns learning games that mix real objects (cards, game pawns) and virtual environments (game board on tablets or smartphones).

Using principles derived from embodied cognition, TUI can increase learning performance by offering sensory perception and feedback (Skulmowski, 2016). Thus, the relationship with objects is not only physical but has also a cognitive dimension. It impacts the way users perceive the environment. The importance of movement and manipulation has often been demonstrated in children education.

Current Limits and Research Questions

In all types of learning environments described above, important research questions remain. Some scientific locks are common; others are more specific to a category of systems. Overall, the main problems concern the cost of designing and building these environments because of their complexity and the high level of interactivity they offer. Budgets can very often be substantial, from several tens of thousands of dollars to several million for some applications (for example, Pulse!! has cost 10 million dollars).

Beyond budgetary constraints, the aforementioned systems generally target a relatively small audience by addressing the development of specific knowledge or skills. It is therefore not easy to have a "return on investment" and their creation is therefore risky. In order to avoid risk-taking and reduce costs, it is desirable to be able to reuse some elements: scenarios, components, resources, game engines, simulation engines, interaction techniques, ... Unfortunately, this capitalization has so far been poorly supported. The main obstacles are related to interoperability difficulties, whether technical (software engineering issues) or semantic (educational science issues).

In order to meet this need for capitalization and also to involve teachers and subject matter experts in the process of designing learning environments, research works have been conducted for several years to propose authoring tools (Murray *et al.*, 2003). The main purpose of an authoring tool is to enable people without any programming skills to design and deliver instrumented learning activities. An authoring tool in education is thus used to create educational environments, ranging from simple resources (content, exercises, etc.) to more complex systems (serious games, simulation, etc.). In the latter case, authoring tools mainly focus on specific situations, such as *e-Adventure* (Torrente *et al.*, 2010) to design point and click adventure games (Fig. 5), *JEM iNVENTOR* (Karoui *et al.*, 2017) to create mobile learning games, or *SimQuest* (www.simquest.nl) to configure physics simulations. The difficulty of these research works is not only technical, but also concerns the support of pedagogical design. It is therefore essential that authoring tools guide teachers by providing them design methodologies related to the kind of interactive learning environment they want to use with their students. The major challenge lies in providing an authoring tool that is, for a teacher, simple enough to quickly create interactive activities and rich enough to set up situations adapted to a particular learning subject and audience.

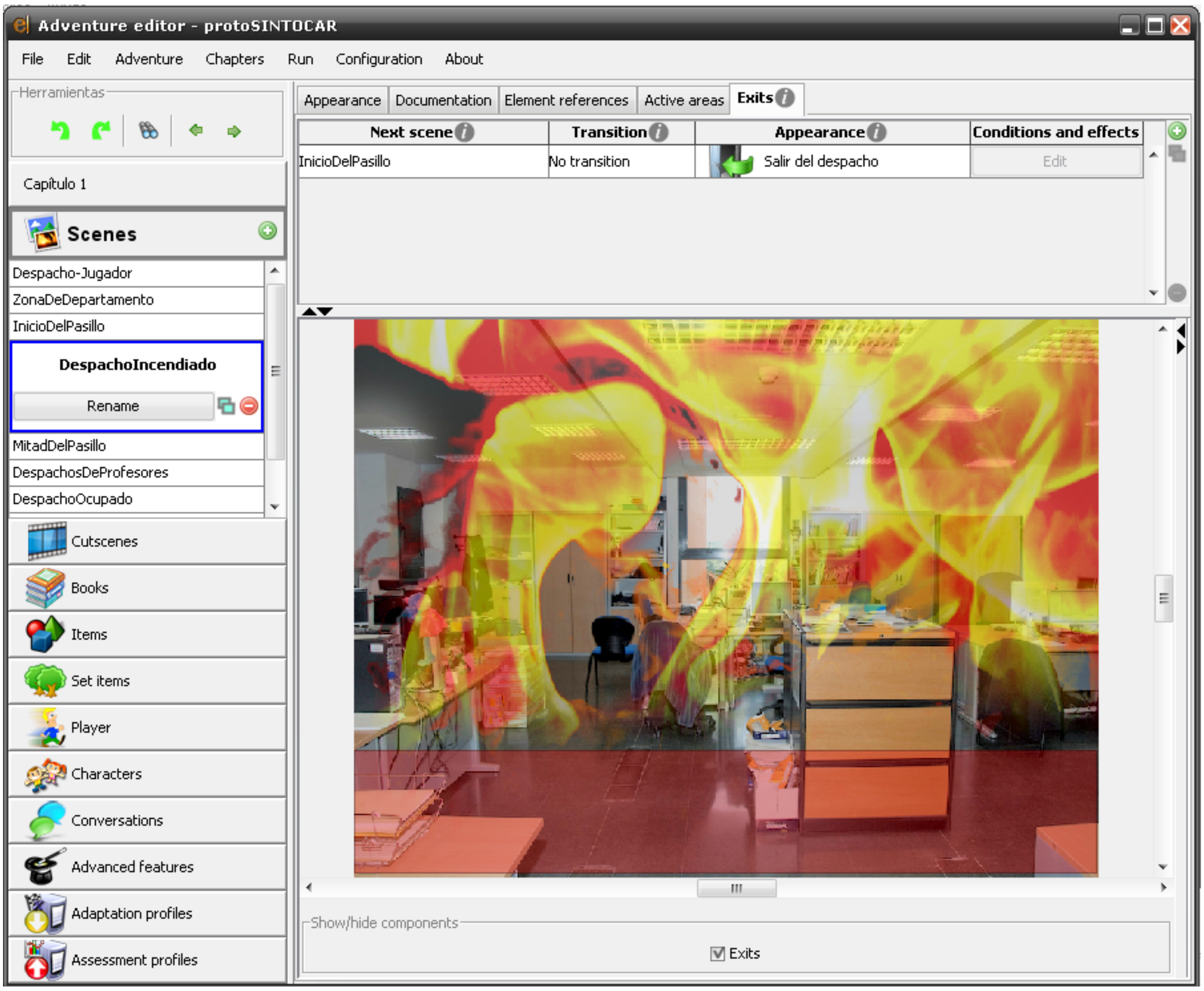

Fig. 5 e-Aventure, an editor to create serious adventure games (source: e-adventure.e-ucm.es)

A research topic to be developed concerns the interoperability between authoring tools. Since they are often specific to the design of specific resources or activities, it would be useful to combine them to propose richer learning situations. For instance, we have seen before that a simulation environment can integrate both real and virtual objects, used in conjunction with a game scenario. The complexity of this type of environment can difficultly be managed without connecting existing authoring tools.

Another research question is related to the use of computer traces that can be collected in interactive learning systems. In these computerized environments, it is possible to gather data on the actions carried out by each learner. Advanced interaction devices also make it possible to have information from sensors (positions, gestures, ...). Data analysis or learning analytics techniques can then be applied to provide semantic information from these raw data. Several uses of these traces are then possible:

- to automatically adapt activities, for instance in the case of learning games, the challenge is to be able to adapt the level of difficulty according to the learners' skills in order to keep them in a state of motivating flow (van Oostendorp *et al.*, 2014);
- to give feedback to students, the objective being to help them to evaluate their actions and encourage reflexivity. The aim is also to make the learners step back from the situation and thus encourage the transfer of learning to other contexts. On these issues, artificial intelligence can lead to major advances. For example, chatbots are already being used for educational tutoring or individual didactic support (Soliman and Guetl, 2013);
- to provide pedagogical indicators in order to enable the teacher to monitor the game and immersive activities (individual and collective). In such settings, educational monitoring and intervention are not easy; the teacher may lack information about the tasks performed by learners. So, the teacher activity support must be a concern before, during and after the instrumented learning activity. On this topic, interesting research concerns technologies to support the teacher in the orchestration of learning activities. For instance, tangible interfaces can be used for the real-time management of events and activities in a classroom (Dillenbourg and Jermann, 2010);
- to inform the designers, or the design team, of the interactive learning activities to help them to redesign educational scenarios and tasks (re-engineering approach);
- to provide researchers with data for the scientific evaluation of the systems (impact on learning, motivation, usability, …).

In connection with this last point and to conclude, it would be important in the future to develop studies showing what kind of activities and what kind of computer support or Human-Computer Interactions should be implemented to promote certain types of learning. Of course, in this area it is important to keep some design freedom, but recommendations, best practices and reproducible methods could helpfully guide teachers and instructional designers.

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