

# A Survey Of Real-World Applications Of Serious Games Technology

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**Abstract.** Serious games (SGs) are video games with serious purposes such as teaching or training and whose principal aim is education. SGs integrate the engagement of video games with the academic and computer simulation worlds, to immerse the player in a safe and entertaining learning environment. Many techniques have been used to improve computer graphics and simulation models in the last few years, leading to the rapid growth in the video games market. At the same time, SGs have been rewarded with the use of these advanced technologies to offer more realistic experiences to the player with educational values within them. In this survey we will look at why some modern games are now classified as SGs and what the definition of SGs should be to encompass them and include virtually endless application fields. We will start with definitions of other game types that have some valuable aspects on learning in order to contrast and relate them with SGs. We think it is very important to be aware of the future of SGs over other electronic teaching methods, courses or learning and training materials. Therefore, we present and analyze several real world application examples of SGs, ranging from the military and education fields to healthcare and advertising. To finish, we conclude on what are the future trends that will follow the SGs Technology and the missing parts that have to be considered to continue and facilitate the development of SGs.

## 1. INTRODUCTION

In the past, Johan Huizinga a Dutch historian considered one of the founders of modern cultural history suggested that the play element has been a driving force behind the development of culture, because of its creative and competitive conflict nature [1]. Nowadays, Marc Prensky a contemporary writer, inventor, futurist and game designer, states that play and learning are beginning to come together and be one and the same and the important way this is happening is through the invention, creation, dissemination and use of digital games for learning and training [2]. Both authors agree with the importance of play and games in culture and learning, however, Prensky refers uniquely to those games played in the digital era: video games which are games developed and played through a computer of some kind.

Video games have grown in such a manner that the game industry has surpassed the movie industry by thousands of dollars in profits since the last few years, and this margin is expected to increase every year. Actually, different gaming industries compete to release the best video game each year, making use of the best hardware and software game technologies, to develop most realistic features with amazing stories and a huge level of fantasy that capture the attention of the player even before the game has been released. The majority of these video games have been used in entertainment, but later it was discovered that some of those games can also be used for more serious purposes. In recent decades many groups of artists, game designers, developers, engineers, researchers, and students in many parts of the world have come together over the internet with the vision of creating a true and positive way of culture generation. A new video game genre was

born called SGs<sup>1</sup>. With this paper we will introduce you to the SGs concept and characteristics, comparing SGs with other video games and other teaching methods; we will also expose some of the practical areas in which SGs can be utilized with some examples of actual SGs. Finally we will look at the areas of SGs that still need further development and where we can continue researching in this area to improve SGs and facilitate its development.

## 2. GAMES ON LEARNING

We will start defining some of the video games that teach or help the player to receive some kind of learning while playing. First we have to state that there are many different game genres and each one varies according to its characteristics; video games can fit into diverse categories like "action, adventure, casual, educational, RPGs, simulations, sports, strategy, puzzles, etc" [3]. Some games are called hybrids because they can fit in more than one category at the same time [4]. We believe that some of the principal video games that have been recognized and useful in helping the player to acquire knowledge or skills in the game are: casual, simulation, strategy, educational, training and skill games. In order to explain why SGs can share most of the characteristics that those video games already have, we will start by defining each one of those genres.

### 2.1 Casual Games

Casual games are one of the most popular games played over the Internet. Their popularity has increased to such an extent that its industry has grown to well over \$600 million in 2004, and industry experts anticipate that by 2008 the market will surpass \$2 billion in the US alone

<sup>1</sup> Although the concept of SG started 40 years ago with games that simulate life but not as electronic games [5].

[6]. These games involve less complicated game controls and less complexity in terms of gameplay, which makes them very popular and accessible to play [6]. The key attributes of casual games are 'fun' and 'accessibility', however, casual games can also train, educate, and improve the gamer's knowledge and skill level [4]. Examples of these games are Tetris, Cake Mania, Bejeweled, Virtual Villagers, etc. Casual games are games that are easy to play and with the main focus on entertainment and relaxation. In this kind of game you can learn how to play the game in less than one minute and master the game in less than one hour.

## 2.2 Skill Games

Skill games are those games that help the player to develop mental or physical skills while playing such as hand-eye coordination and fast reaction times [7]. Skill games are high in interactivity and media integration [8]. The skills that the player can obtain playing the game are unlimited; the more realistic and well-designed the game is, the more skills that the player will learn that could be applied into some real world situation. Most of the skill games played these days, take the form of lightweight web playable games, which make them suitable to be played in online tournaments and players can also make bets as if they were playing in Las Vegas. Because of the amount of money behind these games, players tend to become experts in them and master the skills according to the kind of game that they are playing. Examples of these games are: trivia games, poker and all types of card games, mini-golf, hearts, scrabble, online pool, ultimate tour golf, etc. Skilled games are organized into tournaments that are open and accountable to ensure that players with the best skills win and no cheating is possible<sup>2</sup>.

## 2.3 Strategy Games

In these games the designer creates rules and goals and the players decide which strategies within these rules to take to achieve these goals [4]. Strategy games can also be viewed as "simplified military simulations" with the most classic example being chess, where the player has to build the best strategy to checkmate his opponent [9]. "Traditional strategy games have several advantages: they are familiar to many students, easy to learn, and focused on problem solving" [10]. Strategy games require that the player learns many concepts and skills including decision-making skills. Examples of these games include: board games like anima, checkers, go and mastermind.

In recent years, with the development of game technology, complex strategy games have been developed usually focused on war strategies. Examples of these games are Age of Empires, Anno 1602, and Supreme Commander. These recent strategy games offer more learning to the player, like historical background knowledge, and management and resource allocation of data. For instance, in the game Anno1602

the players have to allocate resources to areas such as plant, production, marketing, and human resources, in order to produce and sell goods. To finish the video game or accomplish a successful strategy, all of this learning and strategy choices should be considered from the beginning of the game, otherwise the player will not have time to re-plan and repair the strategy. Although all of these issues could be helpful to gain good knowledge and learning, the entertainment and fictional characteristics have to be a priority in the design and development of these kinds of games [11].

## 2.4 Simulation Games

A simulation can be considered as a mock-up of an actual or imaginary situation of systems, which can refer to an event (managing simulation) or an artefact (vehicle simulation) [4]. Simulations are used to test and prove the efficiency of models, to understand events in a system, and to perform a task that might be otherwise very difficult, dangerous, inefficient, or impossible to do in the real world [12]. Simulation games are games based on simulations. And these games can have the most complex simulations using high fidelity graphics that helps the player to be involved in the game. Most simulation games involve unreal fictional elements simulating the presence of fantasy worlds, which make them very attractive and entertaining to play and enjoy [12]. The realism used in simulation games has made it possible to use them as training simulators, for example the video game Microsoft Flight Simulator. But not all simulation games are used in training, and not all of them provide to the player an accurate training or learning: it depends of the inner design and level of fantasy that the simulation game offers to the player. Examples of simulation games are Sims, Zoo Tycoon 2, Second Life, etc.

## 2.5 Training Games

Organizations use games in training to help instructors to maintain participant interest, relay concepts, and make the training more enjoyable and fun [13]. The design of training games ranges from the most simplistic formats, to the most revolutionary technologies in video game development. According to their inner design and use, we can classify training games into two broad branches. The first branch and until now most used are those games used to initiate, or terminate a learning event. This kind of training game either precedes a traditional learning session to motivate the learning or breaks up a traditional learning session to test what has been learned so far. The most popular games used in these situations are game shows which are games of TV-style quiz shows<sup>3</sup>. The second branch is the genre of training games that fits in the area of SGs. Examples of these latest games are: Tactical Iraqi and America's Army.

<sup>2</sup> SkillGames, (2000). SkillGames.net: The first Community for Skill Gamers. Web site: <http://www.skillgames.net/>

<sup>3</sup> Training Games, (2000). Game Show Presenter. Web site: <http://www.almorale.com/>

## 2.6 Educational Games

"Although all games are in some way educational, the games in this set are designed with explicit educational goals in mind" [7]. The design of these games varies from text exercises like multiple-choice quizzes, fill in the blanks, or essays to games that make use of complex graphics, stories and animations [4]. These latter games can be considered to be SGs. Some educational games are just a virtual replication of textbooks or traditional paper-pencil format and usually are designed for K-12 children [14]. These types of educational games are very common and they can be found easily over the Internet, but usually these designs are surprisingly ineffective for learning in the longer term, or for adult learning because "the players tend to remember the interactive parts of the game more and not the static text or content" [14]. More complex designs can use dynamic interaction or "can be designed with the help of other entertainment games like adventure games or sport games" to increase the motivation of the player [4]. Moreover, "educational applications can be as complex and serious as visualizations that teach medical students about human bones and organs and the steps involved in performing a medical operation" [15].

## 2.7 Serious Games

To conclude 'games on Learning', we will define SGs and then explain how it is that SGs can share different characteristics of the other video games besides its own characteristics. SGs are those games which make the player a learner and they can be in any application area that offers a relevant and serious purpose to the player. SGs are not new: one of its first definitions states that SGs are those "games that have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement" [5]. One recent definition is: "a serious game is a game in which education (in its various forms) is the primary goal, rather than entertainment" [16]. From both definitions it is stated that entertainment should not be a mayor concern in SGs, but in fact, the fun and engagement characteristics of a game have to be always one of the main goals in the development of the SGs. The principal characteristics of SGs involve pedagogy: activities that educate, train, or instruct [17]. Other characteristics of SGs are that they use entertainment principles, creativity, and technology to build games that carry out serious purposes; they are stealth learning which means learning transferable content without the player realizing it; they allow training to occur in a non-lethal environment; they can reduce the risk of injury to the trainee and damage to expensive equipment by employing low cost simulation techniques; they can be built with smaller teams using existing technology with proven content pipelines; they do not demand high graphics and they could become an important tool in any classroom situation [16], [18].

## 2.8 SGs Vs Other Video Games

From the survey of games described above (sections 2.1 to 2.7) we see a variety of characteristics and games

ranging from high in educational value to high in entertainment value. We can best see how these game categories overlap and fit in relation to each other by representing them in a diagram. Figure 1 below shows each game category as an oval with the corresponding overlapping with other categories. The diagram shows how the SGs category is larger than any other category. It includes several other categories and overlaps with all categories except casual games.

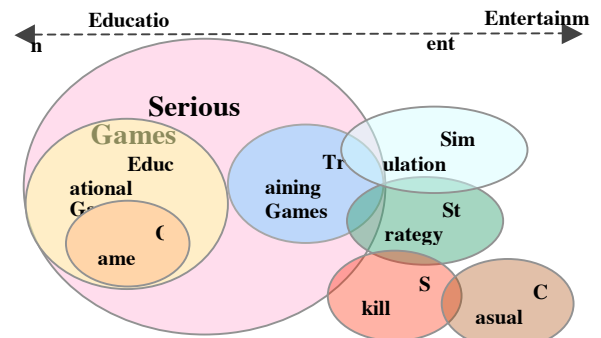


Figure 1: SGs compared with other Video games.

## 3. A COMPARISON OF SGS OVER OTHER TEACHING METHODS

In this section we will review various teaching methods that have been used until now and then follow with the use of SGs in teaching.

### 3.1 Traditional Teaching

The traditional face-to-face classroom teaching environment involves a high degree of lecture with a minimum interaction between the teachers and the students, and is based upon following textbook readings [19]. In the classroom we have an environment controlled by the teacher which restricts the student's creativity and involvement. This leads to a reduced sense of autonomy and a decrease of intrinsic motivation<sup>4</sup> for the student resulting in poorer attitudes and performance [20]. The way in which the teacher explains and prepares his lectures is crucial, because modern students get bored more than ever before with simple text lectures. The problem that is facing traditional teaching with digital natives<sup>5</sup> is that they require more than lectures and a passive way of learning in the classroom. Actually they demand an active interaction which can be developed if we try to use the new technologies in which natives are familiar. In this way we will be able to speak with them in the same language [2]. Some examples of these new technological devices are: electronic boards, computers, LCD projectors, PDAs, television, video games, clicking tools, mobile/cell phones, virtual teachers, educational software, etc.

<sup>4</sup> Intrinsic motivation is the doing of an activity for its inherent satisfaction.

<sup>5</sup> Digital Natives referred to people who have been immersed within digital technologies since their early ages. [2]

### 3.2 Multimedia

Multimedia is a vital dynamic discipline that offers many challenges, interesting problems, exciting results and imaginative applications [21]. Multimedia refers to any computer application that involves text, video/TV, graphics, animation, voice/sound/music, gesture, and other computer activities [8]. With multimedia we can counter-act the static and inflexible text based materials used in the classroom and help students to reduce those deficiencies present in traditional teaching, thus increasing the engagement and motivation in lectures.

Educational multimedia systems promise to make learning easier, more convenient and effective, but the material presented with multimedia alone is insufficient. The teacher needs to guide the material presented in the majority of multimedia applications. For example, classroom teaching enriched by vivid presentations, video capturing of lectures, simulations allowing the exploration of risky experiments, slide-show presentations using multimedia have replaced over-head projector slides. Recent studies have indicated that multimedia learning alone may not significantly increase knowledge acquisition but when a gaming metaphor is employed it significantly increases knowledge acquisition and user enjoyment [8].

### 3.3 E-learning and the Internet

Today's students truly need the Internet; it is a natural resource for education supporting a broad access to resources everywhere in the world and an endless number of opportunities with low cost. The Internet is coming to each and every school to be a part of everyday student activities [22]. If we use the Internet and web system applications as multimedia projects, we can create better ways for learning.

E-learning or distance education is the novel way to take courses at home. This kind of learning is more suitable for students who don't like to travel or cannot travel to the instruction site during school hours, but are intrinsically motivated, for example adult students that seek to satisfy specific life goals such as finishing school while they are working or taking care of their children. On the one hand some students enrolled in e-learning courses have demonstrably more intrinsic motivation than students enrolled in the traditional classroom. But on the other hand other students could have feelings of isolation and lack of direct teacher contact can result in the belief that the student does not belong to a scholarly community [20].

Some examples of e-learning today are virtual classrooms, online workbooks and learning content management systems [23]. The missing part in e-learning courses is the incorporation of methods better suited to the self-regulated learner such as allowing the student a greater role in determining learning objectives, defining learning activities and timelines, and reflecting on how well self-selected objectives have been met in order to facilitate the e-learning teaching [20].

### 3.4 Edutainment

“Edutainment” is an upcoming field that combines education with entertainment enhancing the learning environment to be much more engaging and fun-filled [24]. Edutainment software is one of the quickest growing sectors in the children's software field and because most of the applications developed with this concept were used only in the children sector [25]. But now with the emergence of games technology we can have the evolution of edutainment through serious games. There are many technologies that we can use in order to support the idea of edutainment for example, games, TV programs, films, music, multimedia, etc. Although some people think that edutainment is not a good way to learn because they agree with the statement that all the learning has to be serious, if many teachers could use edutainment and act as entertainment facilitators in the classroom, then students could enjoy more interactive classes while the professor could focus only on monitoring and analysing the performance of students. As a consequence this will save a lot of time and effort from trying to catch the attention of most students [26].

### 3.5 Simulations and Simulators

A simulation is a virtual environment that recreates some form of fictitious or real world environment and is used to test or prove the efficiency of models in a system to optimize or discover its variables and predict events of tasks that otherwise might be too difficult, too inefficient or impossible to achieve in the real world [12]. A simulation is a broad genre of experiences, a powerful technique where we can learn by doing, because we can teach by imitation and replication [8], [18]. A simulator is the result of applying a simulation model to recreate a system or artifact or object of the real world and is widely used for system analysis in management science and operations; in education it is used to offer an environment that promotes the development of mental models in learners, and due to the high cost of producing hardware prototypes, software simulators are used to determine or predict the performance of proposed systems or new design [12].

Some of the problems in using simulations or simulators are their high-cost in development and maintenance. If we want to simulate events of the real world we need all the variables necessary to simulate the real world and that increases the complexity in the design of the simulation model making it more costly to be build and requiring technology that is only available to high-end expensive industrial and military systems or big companies [12]. Its development is risky and can take many years. So when a simulation or simulator artifact is finished it is very important to teach the users to use them in the correct way because every moment that they spend with the simulation or simulator is valuable due to its high development cost and high maintenance cost [23].

### 3.6 Virtual Reality as an Educational Tool

Virtual Reality (VR) is the term used to describe advanced methods of involvement and interaction for humans with a computer-generated graphical (usually 3D) environment, normally referred to as a VR world. VR equipment provides the human with sensory information about the VR world. This can include 3D viewing, sound, touch and smell which have all been employed to stimulate the senses and to increase the illusion that the human is a participant in this VR world [27]. With the fast-growing technological advancements in Virtual Reality (VR) technology and easier access to more affordable computer graphics hardware, it has become possible to create a diverse range of VR applications that are not only focused on scientific research and medical training applications, but now it is also possible to use them with “edutainment” purposes for the general public [24].

### 3.7 Serious Games VS Other Teaching Methods

So far we have reviewed some of the main characteristics of the most popular teaching methods used today. Now we are going to describe how these methods relate to Serious Games. It is easy to observe that the most contrasting method with SGs is the traditional teaching method, and that is because SGs are all about interactivity with the student while the traditional teaching method has the least amount of interaction of all the teaching methods. Another important difference is the engagement produced in the student: while most of the students find tiredness and boredom in the traditional classroom in contrast with SGs they find fun and engagement.

Multimedia rather than the traditional lecture style teaching method, is a more modern vivid way to represent information, and as we saw before, to become an effective educational tool it always needs the guidance of a teacher, while SGs are more like a stand-alone instrument that can make the student learn. However this doesn't mean that the guidance of the teacher is no longer needed, since in the future when we get to have sophisticated authoring SG tools, the teachers will become the most important SG creators.

One of the most important features of e-Learning is the integrated administrative student functions. However, SGs usually don't have these. Another key feature of e-learning is distance education which is also possible with SGs using MMOG.

SGs technology has evolved principally from teaching methods like edutainment, simulations and VR. Therefore SGs cover some of the characteristics from these methods already. SGs are the evolution of edutainment because they extend far past teaching facts to include all the aspects of education for all audiences children, young people and adults [16]. SGs are the combination of simulations and games with non-entertainment purposes [12]. SGs have the potential to simulate the most risky situations of real world challenging scenarios, with the only requirement of

turning on your computer or game console, thus reducing the costs of maintenance that would be necessary with the construction and use of big simulator projects. With the current capacities of hardware and software in games technology, SGs are capable of engaging the player in such a manner that the feeling of immersion in the game is pretty similar to that immersion feeling received from Virtual Reality. But without requiring the expensive and special equipment more than that used for playing a video game.

## 4. SERIOUS GAMES TODAY

The potential market and development that Serious Games have gained in recent years can be demonstrated with the number of conferences that already exist on Serious Games and the game development industry recognizing this new area for commercialization and profits [28]. Serious Games cover just about any non-game industry usage. It covers big budget projects done for the military and also smaller markets like religion, arts, advertisement, etc [15]. SGs are successful today in government and industry where large budgets are available to employ game companies to develop the software. But other markets also need SGs but they lack the budget, tools and expertise to implement the game ideas. There are many possible beneficial SGs applications but they have not been developed due to the development costs. Some of the beneficial SGs that have been implemented are described in the following section.

### 4.1 SGs Major Uses and Application Fields

The market fields in which SGs can be used are unlimited, and in this section we will expose only those relevant examples that have been used with success. One of the pioneer fields in which SGs was used was in the military. All military branches are using or developing a number of entertainment software applications to train soldiers or to recruit more soldiers [29]. SGs can also be used in political and social situations and in almost all business activities [5]. We can think in areas such as politics, war, economics, and interpersonal relations [16]. Areas like health care, corporate training and even the arts can be rewarded with this new technology. In the following table we list some of the main examples of SGs with the characteristics that have helped that specific area of application.

**Table 1: SGs Successful Examples**

Application Field	Characteristics / Usability
Military "America's Army" © U.S. Army 2002	Realistic and gritty. The U.S. Military use this game as a training and recruitment tool.
Government "National Fire Academy Training Simulation" © DAS 1974	LAN networked simulation that allows instructors to present fire fighting situations to their students. The instructor can choose which role each student will play on a student by student basis.
Corporate "Innov8" © IBM 2007	Designed to teach the fundamentals of business process management and bridge the gap in understanding between business leaders and IT teams in an organization.
Healthcare "Maya" © Yourself! Fitness 2007	Personal Trainer. Maya will create a unique, personalized exercise program driven by your specific health and fitness goals.
Education "Tropical America" © OnRamp Arts 2002	The game gives you a journey to unravel the mysteries of the Americas. Features like bilingual, thematic, gameplay, online databases, resources materials, texts and imagery.

## 5. SERIOUS GAMES FUTURE IN EDUCATION

As seen in Table 1 above, major organizations like the military, government, corporations and education have shown the validity and usefulness of these specific areas. These major development projects have raised the profile of SGs and boosted their development and evolution for minor areas. Focusing on education there is so much that has to be done to increase the quality and usability of SGs as another teaching tool in the classroom. First, we have to remember that students of this generation and next generations learn in different ways. Students of today are very used to technology and they use it to learn by its own mediums. They prefer to download the lectures rather than to attend classes, Rather than sitting in a lecture for an hour they can download the whole lecture to their PDAs in seconds and read it in their own time. If this generation of students is totally immersed in technology, it is essential to develop the kind of tools and technology necessary to be able to teach them and gain their attention.

Major future characteristics that should be present in the design and development of SGs in education are that SGs should be able to support assignment, handling and especially grading of homework, to help teachers to test

students while playing, and then teachers can forget the time spent in marking and grading each student [16]. However, if we have a way to measure the knowledge of the players, then we also have to have a way to prevent cheating. It is very important to prevent cheating in the game to assure the teacher that the students are learning the material.

### 5.1 Development of Tools for SGs Designers

Serious games as have been reviewed in this paper are one of the best options to use for teaching in the 21<sup>st</sup> century, because they accomplish most of the requirements that new student generations need. However the development of SGs is complicated. We require a lot of art and hard work and a good cooperation between the academics for pedagogy and the game designer and game developers for entertainment features [16]. This highlights the need to develop game tools that can help us in the development and designs of SGs. Actually there are already some tools that help us to develop games on learning and some game engines that have been used to develop some SGs but these are not enough. We need to create projects or tools more sophisticated than these that can be useful for non-expert programmers to develop SGs [30].

## 6. CONCLUSIONS

We have surveyed the categories of games and the technologies used in education up to today. We have seen that SGs are beneficial for training but have required big budgets for successful outcomes. We conclude that SGs will be beneficial in other areas but that development costs are prohibitive. These costs can be considerable alleviated if low cost tools and methodologies were widely available.

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