Playing at scientists: video games and popularising science

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What differentiates video games from other audiovisual media for popularising science lies in their capacity to transmit knowledge of complex systems through experimentation and experience. Moreover, as a form of popular culture, video games constitute a particularly interesting vehicle to popularise science. The aim of this article is to analyse the potential and limitations of video games in terms of popularising science. To do so, the rules of play are analysed, as well as the player's interactive experience (gameplay) in four commercial video games related to an area of science. The sample selected includes: Crayon Physics*, a laboratory of classic mechanics;* Trauma Center*, where the player adopts the role of surgeon;* SimCity 4*, on town planning, and* Civilization IV*, a journey through universal history.*

Keywords

Video games, popularising science, rules of play, gameplay.

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1. Introduction

This article aims to analyse the potential and limitations of video games in terms of popularising science. According to B. León (1999, 42), the popularisation of science can be defined as "a communicative activity that attempts to provide the general public with certain knowledge taken from science via a new discourse whose purpose and form are not necessarily scientific". In order to attract the general public, León highlights the value of legends and dramatic structures in popularising science (León 1999, 49). Video games, as they form part of popular culture, also constitute a particularly interesting vehicle for popularising science. But beyond this, given that video games allow the simulation of complex systems by means of computational techniques, they are also an ideal medium to transmit scientific knowledge of how these systems work.

The particularity of popularisation via video games is that the content does not need to be explained but rather the player can also be expected to assume the theoretical content implicitly, via experimentation and experience within the context of the simulation.[1] In this respect, to analyse an implicit dimension of the popularisation through video games we cannot limit ourselves to the game's audiovisual surface but must also focus on the internal structures, which can be divided into two broad areas. On the one hand, the game rules: the operational rules (regulating how the player acts) and constituative (*sic*) rules (governing the changes in game status and how the elements in its universe behave) (Salen and Zimmerman 2005, 130). On the other hand, the

1 Concerning this question, see Scolari, C. A. "Interfícies per a saber, interfícies per a fer. Les simulacions digitals i les noves formes de coneixement". In: Scolari, C. A. (ed.): *L'Homo videoludens*. Vic: Eumo Editorial / Universitat de Vic, 2008.

interactive experience designed for the player or the *gameplay* (Rollings and Morris 2004, 59; Juul 2005, 83).

Finally, we should also mention that, in most of the analyses regarding video games' capacity to popularise science, the sample is usually limited to the so-called *serious games*, games created with an explicitly educational purpose in mind and to be used in the classroom. However, the sample we have selected in this article focuses on commercial video games. The reasons for this choice are their social impact, on the one hand, and the fact that this kind of game clearly highlights the tension between the scientific reference and the fun had by the player on the other. Both the potential and limitations of video games in terms of popularising science emerge from this tension.

2. Case analysis

2.1. *Crayon Physics* and classic mechanics

Crayon Physics highlights how scientific knowledge can be transmitted by means of a simple game, both in terms of player interaction and also with regard to the rules that govern how the elements in the game's universe behave.

Created by Petri Purho, *Crayon Physics Deluxe* gives the player an objective (or problem to be solved) that is very simple to achieve, namely that, in a specific scene, a ball must touch the place where there is a star.[2] The game is inspired on the children's book *Harold and the Purple Crayon*, by the North American artist Crockett Johnson, which tells the story of Harold, a 4-year-old boy who creates his own universe with a purple crayon.

For the ball to move in such a way as to reach the star, the player must create objects with the crayon that transmit movement to the ball. The basic rules governing the behaviour of the objects are the laws of Newton from classic mechanics. In this way, for example, the player learns that, if no force is applied to the ball, it will remain in its initial state of rest, in accordance with Newton's first law or Galileo's principle. Although it may seem obvious, this is one of the fundamentals of physics. So the player must create objects that transmit movement to the ball, following the formulation of Newton's second law or the fundamental law of dynamics that also make the ball follow a certain path towards the star. Movement is transmitted by taking advantage of the fact that all the objects created by the player are affected by the law of gravity, which determines their movement, as well as their effect on the rest of the objects created. In this last case, Newton's third law becomes evident, or the law of action and reaction. So these are the three underlying laws in the constitutive rules concerning the behaviour of objects created by the player of *Crayon Physics Deluxe*.

With regard to the interactive experience or *gameplay*, one of the main characteristics of the game is that in each of the stages (the game is divided into different screens in which the objective is increasingly more difficult), there is not one single solution possible so the player can choose from an infinite number of strategies to achieve the objective. This means that the game awakens creativity in the player in resolving problems of greater complexity. At the same time, the player needn't only go for an effective solution but can also try for an elegant one, experimenting with the game itself on the behaviour of the objects created and incorporating beauty to the movement of the ball like, for example, billiard players, synchronising the movements of the objects.

Moreover, the player can also create complex objects such as levers (taking into account the law of leverage and the moment of force) with the help of which the ball can follow a specific path along each arm of the lever or the weights on each side.

Consequently, the game has an interest that goes far beyond achieving the original objective. The game allows players to create systems of bodies that interact with each other under ideal conditions, to verify their behaviour under these conditions and, on the rebound, develop their imagination and creative capacity.

It should be noted that *Crayon Physics Deluxe* is not a definitive version, although the author has announced that this is being worked on. Another interesting fact is that there is a group of programmers adding stages to the original, with scenarios more difficult to resolve and, we hope, with objects related to classic mechanics (such as pendulums,

2 *Crayon Physics* can be downloaded at: <http://www.kloonigames.com/blog/games/crayon>

pulleys, springs, liquids) that will make *Crayon Physics Deluxe* a complete laboratory to experiment with the laws of classic mechanics.

As a final detail, it should be noted that *Crayon Physics Deluxe* has inherited the aesthetics of the cartoon version of Johnson's work: the screen background simulates a crumpled piece of paper where there are different drawings, with the characteristic lines of drawings by small children. The aim, in this case, is to make one of the dreams of small children come true: to make their drawings move.

2.2. *Trauma Center* and surgical operations

Trauma Center: Second Opinion is a video game for the Nintendo Wii console that has been marketed as a "medical simulation", although it's aimed at entertainment. In the game, the player plays the young doctor Derek Stiles, with the aim of successfully carrying out a series of surgical operations with a time limit and increasing difficulty. At the same time, the game also offers narrative interludes, where the story around the protagonist evolves, including his relationships with his colleagues, etc.

Unlike *Crayon Physics*, the connection of *Trauma Center* with the scientific reference is not clearly placed in a single sphere of our two areas of analysis: the rules and the gameplay. In *Trauma Center*, the changes in the status of the game (processed by internal rules and reflected in reactions of the patient's body) follow a certain "realism" but the mechanics to resolve problems are related to a real reference: in this case, the protocols of surgical operations.[3]

In this respect, what is essentially "simulated" in *Trauma Center* is not the behaviour of a natural, social or artificial system but the experience of a subject (the surgeon), using the reference of real surgical protocols. However, as in the rest of the cases analysed, the principles of game design to optimise the fun experience can enter into tension with this reference. Below we provide some interesting examples with regard to this point.

Some of the operations in the first part of the game have objectives like the following: extraction of foreign bodies (glass fragments) from the body of a patient who has been in an accident, extirpation of polyps, repairing a fractured radius and ulna, aspiration of a thrombus, etc. In general, immediately one can see that the procedure prescribed for the player excludes any preparatory or preliminary component to the operation. The player does not take x-rays of the affected zones and neither does he or she give any anaesthetic. *A priori*, it can be considered that the fundamental reason of the designers for ignoring this is the credibility of the player's fictional role, given that x-rays and anaesthesia are normally carried out by other doctors, not by the surgeon. But sometimes the game does require the player to carry out the work of an anaesthetist, such as providing drugs to stabilise the patient's vital signs. We can therefore see here a tension between credibility of the game with regard to the medical reference and the enrichment of the player's interactive tasks to design more dynamic gameplay.

Even regarding the initial stage of the operations, it is interesting that the *gameplay* follows a rigid pattern with regard to access to the patient's affected zone. This pattern consists of disinfecting the zone and making a precise incision with a scalpel. The question is that, in the case of a patient with polyps on the larynx, the play prescribes the same habitual procedure for access to the affected zone (disinfection and scalpel), but in a real operation of this type access is via endoscope, without "opening up" the affected zone. Here we find a deviation from real surgical procedures motivated by a reason that is quite different from the enrichment of interaction: the simplification of certain mechanics of interaction that, in reality, might be judged by designers as not very exciting or excessively complex (at least at this stage of the game).

Concerning this, it is interesting to take into account the fact that the poles of simplification and enrichment of interactivity are closely related to the game's difficulty curve, a highly relevant concept for designers.[4]

Simplifying the reference and enriching interactivity are "deviations" that can make the popularisation of science

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3 For the analysis of this video game, we would like to thank the collaboration of Dr. Miguel Ángel López-Boado, specialist in general surgery and lecturer in the foundations of surgery at Barcelona University.

4 In video game theory, the difficulty curve is usually conceived based on the psychology of optimum experience according to Mihaly

more attractive and, at the same time, graduate the difficulty curve. But, apart from this, "deviations" can respond to different levels of proximity with regard to the reference, from invention to analogy. We can see two important examples in *Trauma Center* regarding this point:

Firstly, in an operation to drain a blood clot in a patient, the player must start by detecting the clot with an ultrasound scan. This is correct medically but before proceeding to drain the clot via the tube (a procedure also in line with reality), the player must stop the clot with the forceps while some others escape. This has nothing to do with real surgical procedure, but added to interactivity increases the difficulty of the challenge, makes it more exciting and fills the scene with suspense. However, this deviation from the real reference is pure invention, inserted in the middle of the game process. As we can see in the next example, such a radical deviation of this type he reference is not necessary in order to make the game more attractive.

In this respect, we have taken a look at the operation for a fractured radius and ulna proposed by the game. The "way to win" in this operation consists basically of draining the blood from the arm, collecting the loose bone fragments and putting them back into place as if it were a puzzle. The intermediate step of these three is false (the bone fragments are not normally extracted), while the other two would be relatively faithful to medical procedure. However, the most interesting thing here is the fact that how the bone fragments are put back together is clearly "idealised" in the game as a puzzle. Nonetheless, this design still has some similarity with the real procedure: putting together bone fragments in the most anatomically possible but without, in reality, achieving the perfect fit between the different pieces. In the game, however, there is a reduction in the complexity of the real operation with pieces that fit perfectly together. The process is also "accelerated" in the game, as the pieces are welded together immediately and magically, unlike the real slow process of welding in bones.

The idealisation and acceleration of this medical procedure undoubtedly are "deviations" from the real reference but of a different nature to the use of forceps to stop the flow from clots (previous example). While the representation of the fracture operation as a puzzle is an idealised and simplified analogy, at heart it is faithful to the real procedure. On the other hand, adding a game mechanism consisting of stopping clots with forceps may make the game more difficult and exciting but it loses its realistic connection with the medical reference.

In summary, we can establish that popularising content via the game involves a dual balance: on the one hand, between the simplification and enrichment of the interactive dimension of the reference and, on the other, between the adding of inventions and analogies with regard to this reference.

2.3. *SimCity 4* and town planning

SimCity 4 is a strategic video game that offers the player the chance to create cities and to experiment with how they function. By assuming the role of mayor, the user manages a city built according to his or her preferences and is responsible for it developing correctly. The main author of the game, Will Wright, based the game's internal rules on different theoretical sources of town planning and the computer modelling of systems.

Firstly, the study by Witold Rybczynski *City Life* (1995), which theorises on a grid model, allows urban expansion via proportional population growth.

Regarding *SimCity 4*, the game, right from the beginning, encourages the grid model, forcing the player to strike a balance between the expansion of the city and population growth. In this way, the player not only acquires knowledge about how the city behaves as a complex system but also about a balanced form of urban development.

On the other hand, when starting the game, the player finds a lot of space to build on. This evokes an observation from Rybczynski: the fact that, unlike Europeans, the first North American town planners had abundant natural

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Csikszentmihalyi (quoted in: Salen and Zimmerman 2005, 351; Juul 2005, 113). Broadly speaking, this theory proposes the notion of "optimum experience" as an appropriate balance between the difficulty of a challenge and the degree of skill/experience of the person with the resources to achieve it. An imbalance towards the difficulty of the challenge would lead to a "frustrating" experience, anxiety and/or impotence. It is the balance between both factors that generates, according to Csikszentmihalyi, a *Flow* or optimum experience. This principle is fundamental in the design of difficulty curves for video games.

spaces. This influences the adoption of a certain model of town planning and, at the same time, encourages the application of free market rules to undeveloped land.

We can relate this issue with the fact that an attempt to represent a social reference such as a city inevitably involves the adoption of a certain ideological point of view. In the case of *SimCity*, its constituative rules reproduce the dynamics of the laws of supply and demand, resulting from a capitalist view of the city. In this respect, Barry Atkins, in his semiotic analysis of the game, concludes as follows: "in SimCity, capitalism isn't only a way of winning, it's the only way to play" (Atkins 2003, 129).

Likewise the theory of *pattern language* by architect and mathematician Christopher Alexander. This theory proposes a generalisation of routines to solve problems associated with certain contexts, from which a categorisation of "patterns" results. For example, a pattern language would represent different rural homes with a similar appearance due to the fact that they share problems and routines of resolution.

In relation to this, in *SimCity* the player gradually learns a "pattern language" for the game, which is evident, for example, in the fact that the residences respond to a limited variety, according to a pattern that is repeated. In this way the landscape becomes uniform, leading to segregation by zones, related to the type of residences built.

Finally, the most important reference in the design of *SimCity* is the theory of urban dynamics by Jay W. Forrester (*Urban Dynamics*). Considered the "father" of system dynamics, Forrester transferred this perspective to the modelling of the behaviour of cities. His theory interprets the city as a complex system that grows and changes over time.

SimCity attempts to reproduce the functioning of a city based on a specific model. This model simplifies the city by selecting the same fundamental variables present in Forrester's theory: housing, industry and trade/business. These subsystems are subdivided into three levels: low density, medium density and high density. The importance of these three variables in the game becomes evident as follows: the stagnation or growth of the city in the game depends to a large extent on the flows of population and, in turn, these flows in population depend on the degree of balance between housing, industry and trade maintained by the player.

But the most particular feature of the case of *SimCity 4* regarding the popularisation of science is that this game adds (and doesn't only take away) complexity to its theoretical reference. Counter to simplification and ideological bias which would "deviate" the game from a strictly pedagogical potential, *SimCity 4* adds variables to the constituative rules that were not in Forrester's original model. In this respect, D. Lobo (2006) states that *SimCity 4* "solves" some problems of its theoretical reference:

> *"Forrester's model applied statistical data to the city as an integral unit instead of treating the effects on a more localised scale. For example, when the model is applied to the police, it observes the relationship between the total number of offences and the number of policemen working in the city, instead of focusing on the different coverage rates of the police and the different trends in crime in each district. The first versions of* SimCity *also used generalising measures on the city but* SimCity 4 *solves this problem, albeit only up to a certain point. The producer of* SimCity 4*, Kevin Hogan, says: "we wanted to take location into account, in such a way that wherever you decide to put the schools has a certain effect."*

So, instead of moving away from reality, *SimCity 4* establishes close similarities with its scientific reference and turns them into a fun recreation of laboratory practices

2.4. *Civilization IV* and universal history

Civilization IV is a game of strategy where the player adopts the role of supreme head of a civilisation. The objective is to make it evolve at an economic, artistic, political, scientific, religious and military level from the 4000 BC to the present day and, at the same time, rule the world.

It is therefore clear that the reference for the game is universal history but specifically from two historical perspectives:

- World history: a discipline developed in the United States that attempts to leave behind the views of history that are excessively focused on the west. So, on the one hand, this discipline focuses on the joint analysis of the different cultures or civilisations and places them at the same level (Stoakes 2001).

  We can find a clear connection between this approach and *Civilization*, as the "characters" in the game are

different cultures that attempt to take over the world: Greeks, Romans, English, North Americans, but also Egyptians, Mayans, Chinese, Indians, Persians, etc. And although each civilisation has its own characteristics, they all have the same chances to win the game.

On the other hand, world history also focuses attention on the economic, cultural, technological and other exchanges occurring throughout history between different cultures, searching for the roots to the processes of coming closer together (which end up leading to the current globalisation) and difference (maintaining identity) characterising the world today (Geyer and Bright 1995).

We also find this aspect reflected in *Civilization*, in the sense that contact with neighbouring cultures can lead to the exchange not only of resources and gold but also of technologies. In other words, establishing contacts with other civilisations is positive for the development of your own civilisation.

- Agroecological history: focusing on the relationships between geography, ecosystems and history. In other words, the aim is to enrich the study of history by analysing the role of resources and geography in the development of different civilisations (Worster 1990).

  In this aspect, *Civilization* also includes this reference, situating (randomly) different resources in the land where each civilisation is installed. These resources will be key to their evolution. For example, if a civilisation has stone in its territory, it will be able to build cities and marvels, such as the pyramids, more quickly; if it has marble, it will be able to construct the Taj Mahal; over time, if it discovers iron, copper, steel, uranium or petroleum, this will also have an effect on its evolution and the relationships it can establish with the rest of the civilisations.

  At the same time, the geography (i.e. the existence of rivers, plains, mountains, deserts), the climate, fauna, flora will influence what a civilisation can or cannot do, where cities will be built, the ease or difficulty of communications between them, etc.

In fact, Kurt Squire (2004), in his analysis of the pedagogical potential of *Civilization III* for secondary schools, points out the link of the video game with these two perspectives. At the same time, Squire also emphasises how the video game can help in learning different political concepts (monarchy, legislation, liberalism, etc.), cultural concepts (alphabet, epic, literature, etc.) economic (currency, banking, etc.), military (gunpowder, weapons, etc.), scientific (perspective, scientific method, fusion, etc.) and religious (polytheism, monotheism, theology, etc.), as well as the relations established between them within the context of history. Therefore, for this author, what *Civilization* teaches us are not the facts of history but history as a complex system in which different elements of different natures interact.

However, the game's popularising potential finds its limits in the tension established between the representation of the reference and the need to turn it into an entertaining game. So, once again, we find significant simplification, common in all simulations, scientific or entertaining, and inevitable if we wish to represent a complex system. In this respect, the selection of aspects that have to do with historical evolution, reducing them to economy, science, religion, culture (arts) and war already is a simplification. At the same time, the elements that go to make up the tree of technologies whose principles each civilisation will be based on throughout its history or even the marvels and the great personalities that appear in the game are also simplifications, around which a debate can be established on the accuracy and precision of the representation of historical facts.

However, beyond these inevitable simplifications, we believe it interesting to talk of other kinds of "manipulations" that have to do with the fact that *Civilization* is a game. So, in first place historical rigour is sacrificed in order to increase the variability of games or *replayability*: for example, the use of different kinds of maps, all of them "fictitious", the random assignment of territory to each civilisation and of resources assigned to each territory, etc.[5]

Secondly, it is interesting to analyse the quantification of

5 In this respect, it is curious to see how Squire, to take *Civilization III* to schools, introduces some changes: he draws up a map of the Earth identical with the real map and adapts the climate conditions, fauna, flora and different resources to those that really existed. So Squire is breaking some of the simplifications and deviations of *Civilization*, befitting its status as a game, to make it a more faithful copy of reality.

the different aspects that form part of each civilisation. In other words, the fact that a certain civilisation in the game advances in the fields of science (discovering writing, the scientific method, fibre optics, etc.), arts (building great marvels, "producing" great artists, developing literature, etc.) or politics ("discovering" legislation, a constitution or universal suffrage) ends up being reflected in the player's score. Finally, not only is each civilisation quantified, but the game also constructs a ranking of cultures and shows us which is the most advanced (and reflects this in different statistical figures).

Finally, and in relation to quantification, we find the presence of competition between cultures (we mustn't forget that the aim of the model player in the game is to rule the world) and, consequently, the pre-eminence acquired by the military aspect. These two elements will also have consequences for the idea that is conveyed of history, as we shall see below.

However, the main limitations of *Civilization IV* as a tool for popularising history are the ideological deviations we find in the representation of this discipline. These deviations result fundamentally from the game's constituative rules. A clear example is "the tree of technologies" and the "principles" followed by each civilisation. Both the tree of technologies (where, in spite of the name, not only technological elements are included but also scientific, economic, religious, etc.), and the principles (of government, legal system, labour conditions, economy and religion) construct the path marked out by the game that must be followed by the different civilisations. So, although the player has a certain margin to choose the time to "research" (adopt) each of the technologies or principles, in reality there is an established order along the path that must be followed, in which a certain element always comes after another. So, for example, at a religious level, we start at mysticism, go on to polytheism and then to monotheism, and we can't change the order of these elements or miss out any stage. Finally, the path taken by all civilisations is the same.

This aspect is very interesting because, through this, we can detect a certain way of understanding and representing history. In this case, what is conveyed via this path that each player/civilisation must follow is the idea of causality and predetermination, as well as progress.

At the same time, if we look at the specific steps each civilisation must follow, we see that *Civilization*'s representation of history falls into a marked Euro-centrism (especially centred on the United States).[6] Given that the links between religious, cultural, political and other elements are fixed, only one history can be played over and over again, and this is western history. So, although we find different civilisations, precisely what is not allowed by the game is to try different evolutions of history. As stated by Bako Bitz (2002), as a player, *Civilization* allows you to be any civilisation although you must evolve like western culture has evolved, thereby becoming *the only history possible*. This is intensified if we take into account the fact that, in practice, the differences between civilisations are minimal (purely aesthetic). Finally, what is staged (and legitimised) is the "western dominance" of the world, magnified by the fact that the model player's objective is precisely to rule the world.[7]

So, although *Civilization IV* allows great strategic variety, the game does not allow this *"what if"* on a historical level, i.e. what would happen if the facts had been different. It only

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6 This can also be seen in more superficial aspects, such as the visual appearance of the characters (the game starts with visible difference between the different civilisations but, as from when we enter the modern age, our characters – workers and soldiers – are dressed in a western style, whatever the civilisation we are playing with) or the fact that all the marvels from the contemporary age are exclusively western.

7 Be it through military dominance (militarily conquering the rest of the civilisations), cultural dominance (cities with "legendary" culture, with a score over 10,000 points and doubling that of their rivals), scientific dominance (winning the race for space in being the first to conquer Alfa Centaury), geographical (being the civilisation that dominates a certain percentage of the Earth's surface), demographic (containing a certain percentage of the world's population), diplomatic (constructing the United Nations, having at least 25% of the territory and of the world population and having good international relations in order to be voted head of the UN) or historiographic (being the first in the ranking of cultures for 2050). This gives us, therefore, a militaristic and aggressive view of the history that Schut (2007) attributes to the nature of the medium.

allows us to represent history as it happened,[8] showing a significant lack of (historical) imagination on the part of the game's designers. This is where we would find its popularising potential (in understanding past facts), as well as its limitations.

3. Conclusions

The main value of video games as a means of popularising science is their capacity to make the functioning of complex systems understandable via experimentation and experience. This characteristic, resulting from the particularities of the medium, is what differentiates its transmission of knowledge from other audiovisual representations. This way of learning, called *learning by doing*, is based on assuming knowledge implicitly, knowledge resulting from the theoretical basis being inserted into the game's rules and gameplay. So commercial video games are a potential transmitter of scientific knowledge, although this is not their main purpose.

However, we have seen that this potential for popularisation often enters into tension with the need to make the underlying theory "playable". Added to this need to model the real reference (inevitable issue), we must add the decisions concerning the game's design, which may either strengthen or weaken this popularising potential.

Firstly, we find a dichotomy between simplifying the reference and enriching its interactive dimension. Simplification makes it possible to represent the reference and, at the same time, makes the underlying scientific knowledge more accessible for the public at large. On the other hand, enriching the interactivity may suppose some deviations from the reference, but in exchange can make the player's experience more entertaining and motivating. In relation to the dichotomy between simplification and enrichment of interactivity we find the importance of design of the game's difficulty curve, which establishes challenges for the player that he or she cannot resolve without previously taking on new knowledge or skills. This therefore encourages the player to learn.

Another element that is related to this tension between a faithful representation of the reference and the game's design is the usefulness of having a factor of variability in the games (*replayability*). This means that each game can be different, although often it involves a distancing from the reference (for example, the random assignment of resources and territories to each culture in *Civilization IV*).

Thirdly, we find the quantification of the elements that go to make up the system represented. Quantification is a necessary feature of the game, encouraging competition and the desire to get better, which are motivating aspects for learning. However, quantification and competition can also project an ideological load on the reference (for example, competition between the cultures found in *Civilization*). In fact, in the video games based on social sciences, precisely the ideology implicit in the game's constitutive rules becomes the main limitation to its popularising capacity.

In general, then, we have seen that the tensions between scientific content and game design revolve around a "risk" of losing information but we have also found a significant case where the opposite happens: in *SimCity 4*, certain rules of the game add information and complexity to the town planning theory on which the game is based

To end, we should note that our analysis has focused on a very specific area: video games as a "text", in order to understand the risks and opportunities of video games regarding the popularisation of science. This approach should be complemented with an analysis aimed at the reception of the game, which would provide greater insight into the relationship between video games, learning processes and the game's social context. Regarding this question, it would be particularly interesting to tackle the exchange of scientific information in virtual communities created around certain video games. One significant example is the case of *Spore*, a video game on the evolution of the species that has recently been published but, before it was even launched, lead to intense debate on the internet concerning the different evolutionary theories that might be implicit in the game's rules. All things considered, it would provide us with greater and better insight into the capacity of video games to popularise science.

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8 We can relate this idea with Nigel Gilbert (1998), who talks of the ineffectiveness of scientific simulation in social sciences to predict the future, and that it should rather focus on understanding the past.

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