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Game On: Exploring the fusion of science and video games through case studies

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Abstract

Nel panorama in continua evoluzione dell'educazione e della comunicazione scientifica, il potenziale dei videogiochi e della gamification è emerso come un argomento di crescente importanza. L'integrazione di meccanismi di gioco ed elementi interattivi in contesti tradizionalmente non ludici, come l'educazione scientifica e la divulgazione, può aumentare la motivazione e l'efficacia complessiva dell'apprendimento. La gamification, ovvero l'uso di elementi di game design in contesti non ludici, è stata ampiamente studiata in vari ambiti, tra cui l'educazione scientifica (Sanmugam et al., 2014). Il potenziale della gamification risiede infatti nella sua capacità di attirare l'attenzione del pubblico, generare un senso di immersione e stimolare la partecipazione attiva nel processo di apprendimento. Sebbene i vantaggi della gamification nell'istruzione siano ampiamente riconosciuti, il suo impatto sull'elaborazione cognitiva e sulla creazione di esperienze di apprendimento significative è ancora un'area che necessita di ulteriori ricerche e indagini. Inoltre, considerando che la divulgazione scientifica può fungere da stimolo per l'apprendimento formale, questo lavoro mira a esplorare l'intersezione tra il mondo dei videogiochi e la sfera scientifica con l'obiettivo di comprendere le dinamiche interattive e influenti tra queste due sfere. Attraverso l'analisi di casi studio specifici, il presente studio si concentra su tre principali aree di convergenza: l'uso dei videogiochi come strumento educativo-scientifico, l'uso della gamification nelle attività scientifiche e il rapporto tra scienza e videogiochi. Questo approccio contribuirà a una riflessione sociologica sulla ridefinizione delle dinamiche partecipative e sul coinvolgimento dei cittadini nella produzione e nella diffusione della conoscenza scientifica.

In the evolving scenario of science education and communication, the potential of video games and gamification has emerged as a topic of increasing relevance. The integration of game mechanisms and interactive elements in traditionally non-game contexts (such as science education and outreach) has the potential to increase motivation and overall learning effectiveness. Gamification, i.e. the use of game design elements in non-game environments, has been investigated in numerous fields, including science education (Sanmugam et al., 2014). Indeed, the potential of gamification lies in its ability to attract the audience's attention, generate a sense of immersion and stimulate active participation in the learning process. Although the benefits of gamification in education have been widely recognised, its impact on cognitive processing and the creation of meaningful learning experiences is still an area that needs further research and investigation. Considering, moreover, that science dissemination can serve as a stimulus for formal learning, this work aims to explore the intersection between the world of video games and the scientific sphere, with the aim of understanding the interactive and influential dynamics between these two spheres.

Through the analysis of specific case studies, this study focuses on three main areas of convergence: the use of video games as an educational-scientific tool, the use of gamification in scientific activities, and the relationship between science and video games. This approach will contribute to a sociological reflection on the redefinition of participatory dynamics and the involvement of citizenship in the production and dissemination of scientific knowledge.

Keywords: science communication; scientific game; serius game

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Theoretical Framework

The advent of digital technologies, particularly the internet, has profoundly transformed the ways in which scientific knowledge is communicated and disseminated. Following the central role played by traditional media – ranging from print to television – in the last century, the internet has introduced a new, more horizontal, interactive and networked communication paradigm. In this context, scientists, science communicators and scientific institutions are carrying out an increasing number of activities on a daily basis, such as sharing data and documents, publishing articles and conference proceedings, editing academic journals and participating in informal exchanges and videoconferences. Pellegrini and Saracino (2019) have defined this configuration as "Science 2.0", describing it as a culture of digital scientific communication based on openness, interactivity, and the online publication of experimental results, emerging theories, and preprints, which are accessible to individuals outside the scientific community. In this context, it is important to consider the social mechanisms through which research results are justified, shared, and recognised as valid knowledge within the public sphere.

The transition from a linear model of knowledge transmission to a dialogic and participatory configuration necessitates a re-evaluation of the methods by which science is communicated, mediated and, ultimately, co-constructed outside the formal contexts of research (Corni et al., 2009). Historically, the field of science communication has been predicated on a deficit model that assumed an audience lacking scientific knowledge to be educated in a unidirectional manner. However, as highlighted in international literature, this paradigm is limited and more interactive and inclusive models are required. One such model is the dialogic model (Sturgis and Allum, 2004; Bucchi, 2008), which values the active contribution of audiences in constructing the meaning of science.

In this context, there is a growing interest in the use of digital tools and interactive environments, including video games, as a medium for science communication and education. Video games, in particular, are experiential environments capable of integrating complex scientific content into engaging narratives and meaningful interactions. These tools diverge from conventional teaching methodologies that rely on the didactic transmission of knowledge, instead proposing immersive experiences that encourage active and reflective engagement. The increasing academic interest in the use of video games in education, including science education, highlights the potential of these environments to redefine the dynamics of learning and to foster a participatory science culture (Fjællingsdal and Kløckner, 2019).

Technologies such as augmented reality and virtual reality are emblematic examples of this transformation. Through the use of simulations and immersive reconstructions, these technologies enable users to explore scientific environments, ranging from the jungle to Earth's orbit, and complex processes such as DNA transcription, amphibian metamorphosis, and neurosurgical procedures. This facilitates an experiential and multisensory understanding of scientific phenomena (Gustafson and Rice, 2020; Canfield et al., 2020; Al-Ansi et al., 2023). The integration of playfulness with an educational dimension is therefore paramount. This duality enhances motivation to learn and promotes the adaptability of content to individual cognitive styles and temporal requirements (Mayo, 2009).

It has been demonstrated by numerous studies that video games function as potent environments for the social construction of knowledge, as they encourage practices

of sharing, collaboration and negotiation of meaning among players (Shaffer et al., 2004; Gee, 2007; Prensky, 2005). The educational potential of these games is evident in their narrative structure and interactive organisation of content, which supports experiential approaches to learning (Antinucci et al., 1995; Van Eck, 2006). Furthermore, the integration of pedagogical principles into gameplay design (Becker, 2007) is a significant contributing factor.

This article aims to explore the relationship between science and video games in the field of public science communication, analysing how some serious games can contribute to the democratisation of scientific knowledge and the construction of technoscientific identities. The objective is twofold: on the one hand, to investigate how scientific content is translated into accessible narrative and interactive forms; on the other, to reflect on the potential of these tools in promoting a participatory scientific culture.

Through a qualitative approach based on case studies, the analysis will focus on a selection of video games that clearly integrate scientific content and are relevant to public science communication. Attention will be paid to the interactive mechanisms, narrative structures and learning processes activated in gameplay. The analysis will be accompanied by a theoretical reflection inspired by the sociology of science and Science and Technology Studies, with the aim of contributing to the debate on the evolution of the spaces and languages of science in the digital age.

What kind of relationship between science and video games?

In recent years, video games have emerged as one of the most dynamic and pervasive media languages globally, engaging over 2.5 billion people worldwide[1]. Initially conceived as entertainment tools, they have progressively entered the fields of education and science communication, attracting the interest of a variety of disciplines, from cognitive science to pedagogy, to social studies of science and technology.

The increasing use of so-called "serious games" in educational settings (Wouters et al., 2013) reflects a cultural shift that Prensky (2001) defines as "digital game-based learning", where the playful element is recognised as a valuable educational tool. Video games differ from previous media in that they are structurally interactive, involving the active participation of the user in constructing the narrative and resolving complex problems (Chirchiano, 2017). Unlike other media, which are consumed passively, video games encourage situated action, placing the player at the centre of an interactive environment governed by constraints and cognitive objectives.

Numerous empirical studies have investigated the effectiveness of integrating video games into subjects such as mathematics, science, geography, languages and computer science. These studies have found that integration increases student motivation and engagement, as well as improving conceptual understanding and cognitive performance (Klawe, 1999; Papastergiou, 2009; Virvou, Katsionis and Manos, 2005). These results have led to critical reflection on the role of video games,

[1] WEPC (2018). 2018 Video Game Industry Statistics, Trends & Data. Available at https://www.wepc.com/news/video-game-statistics/#video-gaming-industry-overview

not only as auxiliary teaching tools, but also as potential vehicles for reconfiguring the educational paradigm (De Aguilera & Mendiz, 2003).

In the context of public science communication, which is characterised by an increasing demand for accessibility, interaction, and the diversification of languages, video games present themselves as a medium that can engage non-specialist audiences by activating cognitive and emotional processes through narrative and immersive modes. The STEM (Science, Technology, Engineering and Mathematics) field in particular has recognised the significant potential of these tools in promoting scientific literacy and stimulating interest in techno-scientific careers (López and Cáceres, 2010).

The interactivity typical of video games promotes participatory learning, whereby scientific concepts are explored, experimented with and contextualised through situated practices and problem solving, rather than simply being transmitted. As Valentine and Jensen (2016) have highlighted, video games can contribute to the development of critical thinking, creativity, and the ability to make informed decisions in uncertain situations by simulating complex scenarios. In this sense, science education mediated by digital games provides an interactive and engaging environment that makes specialised content accessible and memorable.

Recent literature demonstrates that gamification and game-based learning can have a positive effect on cognitive abilities, improving memory, comprehension and scientific reasoning skills (Sanmugam et al., 2014; Morris et al., 2013). Furthermore, video games' ability to integrate scientific content into compelling narratives enables effective mediation between expert knowledge and the non-specialist public. This dynamic creates opportunities for closer interaction between the scientific community and the cultural industry, generating scenarios for the co-production of knowledge aimed at democratising knowledge and strengthening a participatory scientific culture.

Within the theoretical framework of Science and Technology Studies (STS), video games can be interpreted as "boundary objects" (Star and Griesemer, 1989) that connect diverse social groups — including educators, researchers, developers, students and citizens — through shared learning, exploration and scientific storytelling practices. In this sense, they are not only educational tools, but also epistemic environments in which the meanings, values, and representations of science are constructed and negotiated.

Case studies of scientific serious games

In the field of public science communication, the emergence of serious games represents one of the most interesting developments in the relationship between technoscience, digital culture and participation. These are video games designed explicitly for educational, training or informational purposes, which retain the playful dimension typical of the video game medium, but subordinate entertainment to cognitive and social objectives (D'Aprile and Ulloa Severino, 2016; Durkin, 2010). In contradistinction to conventional video games, serious games are designed to stimulate active learning through immersive interaction, problem solving and critical thinking, thereby assuming a primary educational function. These technologies have been employed across a diverse range of domains, including but not limited to: educational institutions, academic instruction, professional and

military training, health promotion, civic engagement, and social and political marketing (Ritterfeld et al., 2009).

In order for a serious game to be effective in a learning process, the integration of three fundamental dimensions is highlighted in the literature: namely, simulation, playfulness and educational purpose (Anolli and Mantovani, 2011). Simulation allows users to experience realistic environments and dynamics, facilitating situated learning; the playful component introduces mechanisms of motivational engagement; finally, educational intent directs interaction towards the consolidation of specific skills and knowledge (Giampaoli et al., 2020). The combination of these elements results in gaming serving as a motivating environment, with the capacity to facilitate complex cognitive processes in a manner that is both accessible and engaging.

From this perspective, serious games can be interpreted as socio-technical tools for mediating scientific knowledge. It is important to note that these games do not merely convey content, but rather configure participatory learning spaces in which players, through interaction, construct an active understanding of scientific phenomena. In the field of STS, these tools are regarded as cultural technologies that contribute to the popularisation of science, leading to the redefinition of its epistemic boundaries and the strengthening of the legitimacy of non-expert knowledge (Shapin, 1995). Science, historically inscribed in closed domains reserved for highly specialised epistemic communities, is thus recontextualised in interactive digital environments that are more permeable and inclusive.

The approach adopted in this study is predicated on the recognition of a fundamental tension between epistemic exclusivity and cognitive openness. This study will examine three serious games from the perspective of the sociology of science. These games are configured as media devices capable of translating complex knowledge into accessible experiences. This contributes to the democratisation of scientific knowledge. In particular, the field of space science – traditionally the domain of experts and specialist agencies – offers an exemplary field for observing how playful technologies can open up new forms of public engagement and the construction of shared meanings.

At this point, it is useful to distinguish between related, yet not interchangeable, concepts. While the term “serious game” is sometimes used interchangeably with “applied game”, the latter more specifically refers to games designed for concrete application contexts, such as clinical, corporate, or institutional settings, with an emphasis on adaptability to specific training or operational needs (Schmidt et al., 2017). In contrast, gamification is a design strategy that involves introducing typical game elements, such as points, levels, goals and rewards, into non-game contexts to encourage user engagement and participation (Deterding et al., 2011). In other words, serious and applied games are complete games with educational or functional objectives, whereas gamification does not involve constructing a game in the strict sense, but rather adopting playful dynamics as a motivational tool.

In summary, serious games represent a significant interface between scientific culture and digital environments, offering a privileged laboratory for observing contemporary transformations in science communication. As hybrid tools — cognitive, technological and symbolic — they encourage critical reflection on how science is narrated, learnt and discussed in the public sphere.

This paper analyses three serious games which represent paradigmatic examples of technoscientific mediation through different interactive and content-based approaches. The selected cases — Kerbal Space Programme, Niche: A Genetics Survival Game and Gran Sasso Videogame — stand out for their ability to integrate complex scientific content into coherent, playful structures. This contributes to the construction of shared meanings and democratic access to knowledge. Each game is analysed sociologically as a media artefact that can configure cognitive and participatory spaces for public scientific understanding.

Kerbal Space Program

The Kerbal Space Programme (KSP), which was published in 2011 by the Mexican studio Squad and designed by Felipe Falanghe, is a prime example of a serious game that integrates advanced scientific content into an accessible and engaging gaming environment. Based on a semi-realistic simulation of the laws of physics as they apply to aerospace engineering, the game offers users the opportunity to design, assemble and pilot rockets, satellites and space probes, as well as carrying out complex interplanetary exploration missions.

The game is divided into two main components: a spacecraft building editor and a physical simulator that allows missions to be tested within the fictional Kerbol solar system, which is governed by realistic gravitational and mechanical laws. The initial goal is to escape the atmosphere of the home planet, Kerbin (an analogue of Earth), before tackling increasingly complex challenges such as orbital rendezvous, moon landings, space station construction, interplanetary transfers, and re-entry missions.

What sets KSP apart in the educational gaming landscape is its experiential learning approach based on trial and error. Participants are exposed to continuous trial and error, creating an incremental learning environment in which understanding scientific principles is directly linked to practice. This approach reflects an epistemic model based on enquiry and autonomous knowledge construction, in line with the constructivist tradition of learning.

From an STS perspective, the Kerbal Space Program (KSP) represents a socio-technical environment in which technoscientific identities are constructed (Haraway, 1991; Latour, 1987). Through gameplay, players do not merely consume scientific content passively; they take on active roles as designers, scientists and engineers, thereby symbolically participating in the process of technoscientific knowledge production. This involvement enables players to explore the epistemic, ethical and material dimensions of space science in a playful manner.

As Mallory (2019) notes, the introductory training missions guide players through the game's controls and engineering logic and serve a crucial educational function by gradually introducing the technical language of rocketry and orbital mechanics, enabling players to develop an accessible yet rigorous understanding of complex scientific concepts. While some simplifications are necessary for playability, the simulation remains remarkably faithful to the fundamental principles of physics, a fact that has earned praise from the scientific community, including scientists and astronauts (White, 2014).

Niche - A Genetics Survival Game

Developed by Stray Fawn Studio and released in 2017, Niche – A Genetics Survival Game is a strategic simulation game that focuses on genetic and evolutionary dynamics within animal populations. Players manage a group of creatures that are morphologically a cross between canines and felines, controlling their reproduction, genetic trait transmission and progressive adaptation to the environment. The aim is to ensure the survival of the species by optimising the gene pool and influencing processes such as natural selection, mutation and ecological adaptation.

Players can select and control the reproductive process of their species, ensuring its survival through evolutionary mechanisms such as natural selection, genetic mutation, and environmental adaptation. In this sense, Niche is a genetic survival simulator in which managing an animal population's genetic heritage is key to improving its ability to adapt to environmental challenges. From a sociological perspective, the game can be interpreted as an artefact that reflects and constructs meanings around science, particularly genetics and biological evolution. In doing so, it contributes to a greater collective understanding of complex scientific concepts through an interactive medium.

The game gives users the responsibility of guiding the genetic development of a species to ensure its survival. This reflects the broader social debate on the ethical implications of genetic manipulation (Fahn, 2020; Almeida & Diogo, 2019). In some ways, Niche reflects a model of "genetic anthropocentrism", in which the player takes control of evolutionary processes and exercises what Foucault (1976) defines as biopower. The game offers the player almost total control over the evolutionary trajectory of the animal population. This power is utilised to manage scarce resources and adapt to shifting ecological circumstances, underscoring the significance of the interplay between complex systems, living entities, and the environment as a foundation for grasping social dynamics (Hannigan, 2014).

The game has been well received in educational settings, where it is used to promote active learning and engage students in interdisciplinary pathways combining natural sciences, ethics, and transversal skills (Prensky, 2001). Its free availability to schools has increased accessibility to the tool and contributed to the adoption of alternative teaching models that prioritise exploration, simulation and experimentation as essential components of public scientific understanding.

Gran Sasso Videogame

Developed in 2018 as part of the PILA (Physics In Ludic Adventure) project, Gran Sasso Videogame is a great example of how scientific institutions, communication professionals and educational organisations can collaborate. Created through a collaboration between the National Institute of Nuclear Physics (INFN), the scientific communications agency Formicablu and the National Institute for Documentation, Innovation and Educational Research (INDIRE), the video game aims to introduce students, particularly those aged 14–19, to the world of contemporary physics by offering an immersive and interactive experience.

The project's innovative nature lies not only in its complex and specialised content, but also in its narrative approach. The game revolves around Zot, an alien who is catapulted to Earth by a space-time anomaly and finds himself in the Gran Sasso National Laboratories, one of the world's largest underground centres for fundamental physics research. In order to return home, Zot must complete a series of experiments inspired by real research conducted at the laboratories, ranging from nuclear astrophysics and the study of dark matter to neutrino-less beta decay and the observation of solar neutrinos. Each experiment has been translated into a mini-game, developed in collaboration with scientists and science communicators through a process of mediation that reflects the principles of public engagement with science (Bucchi & Trench, 2014). The visual language, game dynamics, and concise yet rigorous teaching materials constitute an integrated system that aims to make

advanced concepts accessible without excessive simplification by progressively constructing meaning within the context of a playful experience.

From a sociological perspective, the Gran Sasso Videogame is a narrative device that redefines scientific communication as an inclusive, dynamic and interactive practice. Rather than being a passive user, the player is encouraged to actively participate in the simulation of scientific activities, experiencing the logic of protocols, the complexity of measurements, the uncertainty of data, and the theoretical challenges of fundamental physics research first-hand. In this sense, the game fosters a sense of scientific citizenship, encouraging familiarity with scientific environments and offering insight into their operating dynamics.

In line with STS approaches, the video game can also be interpreted as a "visibility device" (Bruno et al., 2020), capable of rendering the theoretical concepts of physics and the material and social infrastructure of research tangible. Set in the Gran Sasso Laboratories, which employ over 1,100 researchers from 29 countries and operate in five main areas of research, the game showcases Italian scientific excellence through playful storytelling. It contributes to constructing a collective imagination of science that goes beyond the abstract representation of theories and shows the places, practices, and human networks that make it possible.

Conclusion

The present study investigated the use of science-themed video games as tools for cultural mediation between expert knowledge and non-specialist audiences. The analysis of the selected cases highlights how these games are not limited to the transmission of disciplinary content, but rather operate as socio-technical interfaces that enable forms of experiential learning, cognitive activation and symbolic participation in the production of scientific knowledge. In accordance with Miller's (2013) proposition that scientific and technological developments contribute to the formation of collective future-oriented narratives, this study explores the potential of video games as a medium for the exploration, negotiation and reinterpretation of such narratives.

The serious games analysed – Kerbal Space Programme, Niche and Gran Sasso Videogame – demonstrate the efficacy of the utilisation of playful language in promoting conceptual understanding, in addition to its ability to stimulate critical thinking, complex problem solving and reflection on the ethical, social and political dimensions of science. The interactive and immersive nature of these games is particularly salient in the promotion of situated learning, whereby scientific knowledge is evaluated within narrative and simulated environments that are capable of stimulating players' intrinsic motivation (Morris et al., 2013).

At the same time, there has been a growing interest in integrating video games into citizen science projects, which involve non-expert citizens in the processes of collecting, analysing, and interpreting scientific data (Curtis, 2014; Nielsen, 2012). These practices reflect an evolution in the public's role from passive recipient to active co-producer of knowledge, thereby contributing to the redefinition of the boundaries between science and society (Bonney et al., 2014). Interaction between the scientific community, game developers, and citizen players thus opens up spaces for new forms of interdisciplinary collaboration and experimentation with alternative communication methods.

However, using video games for scientific communication comes with challenges. The main challenges include ensuring the accuracy of scientific content, avoiding excessive gamification at the expense of educational substance, and designing meaningful experiences that balance epistemic rigour and playful engagement. Gee (2003) observes that designing effective video game environments for learning requires carefully integrating playful dynamics with coherent pedagogical structures.

In conclusion, science-themed video games are transformative tools with great potential for public science communication. They promote understanding and interest in scientific content and contribute to the construction of a more participatory, reflective and democratic scientific culture. Through play, science leaves laboratories and classrooms to enter everyday, familiar, digital environments, offering new ways of interacting with knowledge that deserve critical attention and further empirical exploration by sociological research.

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