Sustainability Learning through Gaming: An Exploratory Study

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Abstract: This study explored the potential of digital games as learning environments to develop mindsets capable of dealing with complexity in the domain of sustainability. Building sustainable futures requires the ability to deal with the complex dynamics that characterize the world in which we live. As central elements in this system, we must develop the ability of constantly assessing the environment that surrounds us, operating in it and adapting to it through a continuous and iterative individual and interpersonal process of revision of our frames of reference. We must focus on our world as a whole, considering both immediate problems and long-term consequences that decision making processes could generate. Educating for sustainability demands learning approaches and environments that require the development of systems thinking and problem-solving, rather than solely the acquisition of factual knowledge. When designed with complexity in mind, digital games present a high potential to facilitate sustainability learning. Digital games can be modelled as 'complexified' systems, engaging players in cognitively demanding tasks requiring problem-solving and decision-making skills to deal with ill-structured problems, unpredictable circumstances, emerging system properties and behaviours, and non-linear development of events. Furthermore, games can require players to collectively engage in the pursuit of common goals, promoting remote interactions across large numbers of players. To understand how games are currently used for "learning for sustainability", we analysed 20 games. In spite of the potential offered by digital games and concrete examples of good practice, we found that sustainability thematic contextualisation and complex system dynamics are not leveraged as much as could be expected. Hence, there seems to be space for improvements oriented at creating game systems requiring players to address sustainability issues from multiple perspectives through: contextualisation integrating the social, economic and environmental dimensions of sustainability; gameplay dynamics integrating non-linearity, emergence, uncertainty, ill-defined problems and social interactions.

Keywords: sustainability, complex systems, game-based learning, digital games

3. Introduction: The focus on sustainability

Over the last 40 years, there has been an increasing interest in supporting sustainable development to manage limited resources in a world facing growing population, industrialization and globalization. Although much work has been done, progress has been slow. In 1972, the international community met for the first time in Stockholm to analyse global environment and development needs. The resulting Stockholm Declaration and Action Plan defined principles for the preservation and enhancement of the natural environment, highlighting the relationship between environmental and developmental issues.

After the Stockholm Conference, the United Nations organised two summits on sustainable development in Rio de Janeiro (1992) and Johannesburg (2002). The concept of sustainability became increasingly popular and used in our common language as well as in important strategies and policies promoting sustainable development.

Although much work has been done since 1972 to define and support sustainable development, progress has been slow. As stated by the Secretary-General of the UN (2002), throughout the years the concept of sustainability '(...) has become a pious invocation, rather than the urgent call to concrete action that it should be. And while sustainable development may be the new conventional wisdom, many people have still not grasped its meaning.' (§ 3). Consequently, there is an urgent need to promote new ways of learning and thinking to help societies shift towards a more sustainable development (Tilbury and Wortman 2004).

This paper presents an exploratory study examining how games are used to educate for sustainability. It constitutes the preliminary phase of a research programme aimed at investigating how the science of complexity can guide game design to leverage the potential of game-based learning for the development of sustainable mindsets.

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4. Conceptual framework

4.3 Defining sustainability

Sustainability is a constantly evolving concept (UNESCO 2005), involving multiple fields and perspectives, and related to very diverse phenomena. t is therefore extremely difficult to unified definition of sustainability that is at the same time broad and specific to suit the diversity of contexts sustainability relates to. Consequently, sustainability has been inconsistently interpreted and only partially understood, often leading to inadequate and contradictory policies (Lele, 2002).

The UN World Commission on Environment and Development provided through the Brundtland Report the most widely used definition of sustainability, outlined as '(...) development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' (UNWCED 1987). Albeit criticised for not explicitly mentioning the importance environmental sustainability, this definition is considered an important foundation, as it involves the ethical and intergenerational aspects of sustainability, implicitly addressing the idea of an harmonious development that incorporates not solely the economy but people and ecosystems as well (Gardiner 2002). Accordingly, sustainability is nowadays generally conceptualised in terms of the "Triple Bottom Line" (Elkington 1999), a concept involving three dimensions:

- *'Economic: An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectoral imbalances which damage agricultural or industrial production.*
- *Environmental: An environmentally sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions, and depleting non-renewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources.*
- *Social: A socially sustainable system must achieve distributional equity, adequate provision of social services including health and education, political accountability and participation.'* (Harris 2000, pp.5-6).

Although individual logics govern each of these dimensions, the three of them are tightly coupled, and their interplay originates global systemic effects that cannot be fully understood or predicted based on local events. This defines the complex nature of sustainability.

4.4 Education and the sustainability mindset

Dealing with the complexity of sustainability requires significant changes in government policies, social and cultural values, and public attitudes and behaviour. These changes are not straightforward, as they call for an important shift in the perspectives that individuals and societies hold in relation to the world and their role in it. In order to foster the changes needed, in 2002 the UN proclaimed the Decade of Education for Sustainable Development, 2005-14, promoting the key role of education for the acquisition of knowledge and the development of skills and attitudes necessary for achieving sustainable development and face present and future challenges. A key postulate of this initiative is that a sustainable future is only possible if we understand the systemic interrelations among environment, economic growth and social development. Therefore, education should help developing our ability of constantly assessing the environment that surrounds us, operating and adapting to it through continuous and iterative individual and interpersonal processes of revision of our frames of reference. We must learn to focus on our world as a whole, considering both immediate problems and long-term consequences that key decisions could generate, through a trans-disciplinary approach, and at both an individual and societal level.

Consequently, it is now understood that in order to deal with and engage in sustainability, more is needed than just knowledge concerning sustainable development (Tilbury 2004; UNESCO 2005).Although domain-specific knowledge is relevant, it is equally important that we, as central actors, develop skills, attitudes and capacities necessary to engage in sustainability with "heads, hearts and hands" (Sipos, Battisti and Grimm 2008). The literature on education for sustainability (Tilbury 2004; Tilbury & Wortman 2004; UNESCO 2005) has identified several characteristics of a sustainable mindset which enable individuals to engage in sustainable behaviours (Figure 1).

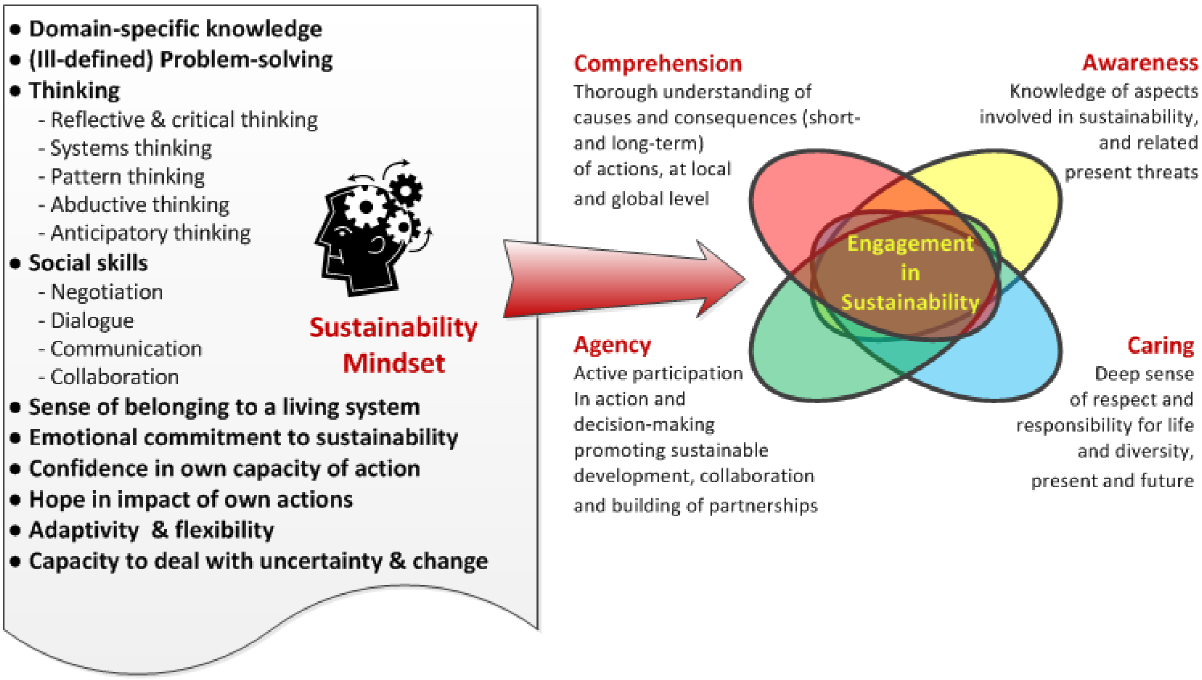

Figure 1: Sustainability mindset and engagement in sustainability

Educating for sustainability demands approaches and learning environments promoting and facilitating the development of systems thinking and learning for complexity (intended as the development of mindsets and skills required to deal with essential traits of complexity, such as change, uncertainty, and global phenomena emerging from local dynamics). As Dieleman and Huisingh (2008) emphasise, traditional western education is strongly focused on analysis and deconstruction. We are taught and encouraged to analyse wholes in parts, decomposing complicated systems in an effort to understand them through their elements. This reductionist approach contradicts the very nature of complex systems, which cannot be understood as wholes just by analysing their parts (McDaniel and Driebe 2005; Miller and Page 2007; Patton 2010). Consequently, we are poorly equipped to comprehend elements and interdependencies in complex systems. Dieleman and Huisingh (2008) pinpoint that the lack of cognitive tools appropriate to explore and comprehend systemic complexity lead us to fall back to analysis, being this a more familiar way of knowing and learning. Furthermore, Tilbury and Wortman (2004) indicate that educators are too often provided with resources which address the theory of education for sustainability, but fail to offer relevant examples of tools and approaches that may be used to facilitate the implementation of the theory. Hence, there is an urgent need for tools and educational models fostering systems thinking and facilitating learning for complexity.

Due to their characteristics, digital games can highly benefit learning for complexity. In fact, they can be regarded as excellent educational environments, supporting knowledge and skills learning through fun, in situated and meaningful contexts. Furthermore, digital games can address complexity, requiring players to deal with ill-structured problems, unpredictability, emerging systemic properties and behaviours, and non-linear development of events. Finally, gaming environments can support remote interactions across large numbers of players, requiring collective engagement in the pursuit of common goals. We explore this in more detail in the following sections.

4.4.1 Learning in games

The educational value of digital games and simulations has been theorised and empirically investigated for more than 20 years. Different authors identified numerous reasons why games can be considered educational tools, such as: the intrinsic motivation stimulated in games (Malone & Lepper 1987); the experiential learning occurring while playing (Dieleman and Huisingh 2006); the presence of pedagogic principles in game design (Becker 2007); and the access to shared social practices for the construction of knowledge (Gee 2007; Steinkhueler 2008). In our past research, we have outlined the characteristics shared by good games and good learning environments, and identified the intrinsic connection between fun and learning in games (Fabricatore 2000; Fabricatore and López, 2009; López 2010).

The very same nature of the gaming experience makes digital games valuable tools for learning for sustainability. Most digital games require players to engage in activities organized as a sequence of steps involving different thinking processes, skills and knowledge (Figure 2). First, players identify or define a goal to accomplish in the game. Goals can be partially or completely undefined, thus challenging players to complete their definition through exploration, deduction and inference. Then, players plan how to achieve the set goal, relying on problem-solving, decision-making and creativity. When planning players define one or more suitable courses of action, understand purposes, forecast outcomes, and manage available resources optimising their use. Planning is followed by action, which requires putting into practice the knowledge and skills acquired in the previous stages. Through action players are challenged to develop different types of skills and knowledge depending on the type of game, (e.g. psycho-motor skills; communication and negotiation abilities; attention; memory; rhythm; and timing, among others). While acting, players assess intermediate outcomes and relevant changes in the game state, deciding whether to continue, modify, or abort the current plan. After action is taken, players assess the final outcome. Based on this assessment they set goals for future planning, starting again the cycle. During the game play a spirit of enquiry is needed to explore different scenarios, and reflection and adaptation are required to deal with uncertainty, accept failure and investigate alternate strategies.

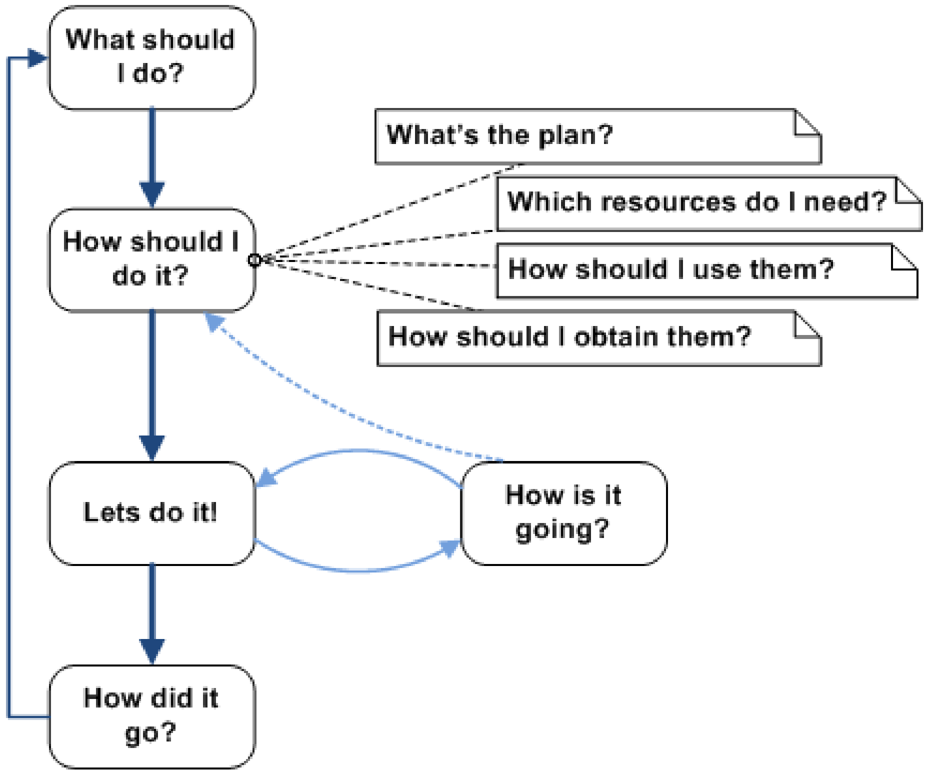

Figure 2: Articulation of the game experience (Fabricatore and López 2009)

All these steps are carried out directly in the gaming environment that serves as a frame for meaning making (Gee 2007). Players receive just-in-time feedback, affording a situated and systemic understanding of the consequences of their actions. Furthermore, games foster the collective construction of knowledge, collaboration and sense of belonging by stimulating players to discover and discuss within the gaming community how to tackle game mechanisms, quests, rules and stories that define the game world (Steinkuehler 2008).

The contribution of digital games to education for sustainability also depends on their extraordinary potential to motivate players and emotionally engage them in the game dynamics. Emotional involvement and commitment is essential to engage in sustainability, the same way that motivation and fun are fundamental to engage players in the game. The key principle to motivate and engage players in learning processes is leveraging the intrinsic connection between fun and learning (López 2010). It is known that we learn more and better when we enjoy what we are doing, but the link between learning and fun in games is actually much deeper. In order to play a game, players must learn about elements of the game system such as goals, entities and rules, and develop individual and social skills required to succeed. Fabricatore (2000, 2007) emphasizes that meaningful learning is not only required in games but is actually a major determinant of motivation. If players do not have anything new to learn, discover, develop or improve they will not feel challenged. Consequently, their motivation will drop and they will stop playing the game. On the contrary, new challenges motivate players to continue playing and engage in further learning, exploring alternatives, increasing their knowledge, discovering mechanisms and improving their performance to progress and develop their mastery. Thus, learning can be considered an essential determinant of the game fun (Fabricatore 2007), engaging players at a cognitive, emotional and conative level. This is precisely what education for sustainability needs.

4.4.2 Games as complex systems

Any digital game can be considered a system, intended as a whole composed of parts which are interconnected and interact so that the system maintains its existence through the mutual interaction of its parts. At any given time the state of a game system is defined by the on-going dynamics and the current state of the system components (Meadows and Wright 2009).

In a game system players play in order to fulfil game aims through the achievement of game goals, interacting with other players and game entities, and engaging in challenges and artificial conflicts resulting in quantifiable outcomes (Salen and Zimmerman 2003). Interactions among players and game entities originate game system dynamics. Game system dynamics can be either triggered by the player or by other game entities, regardless of the decisions of the player (Fabricatore et al. 2002).

Digital games can be merely complicated or properly complex systems. Complicated systems are composed of large numbers of elements and interrelations. Elements maintain a degree of independence from one another, can be fully understood in isolation, and interact based on predefined rules. Hence, complicated systems are knowable, and their behaviour can be predicted examining their parts and the laws that govern interactions among parts, although their study can be challenging (Miller and Page 2007; Quinn Patton 2010).

Complex systems too comprise large numbers of interacting and interconnected elements. What distinguishes them from complicated systems is, first and foremost, the phenomenon of emergence, whereby '(…) well-formulated aggregate behavior arises from local behavior.' (Miller and Page 2007, p.46). Hence, in complex systems interacting elements originate dynamics which cannot be predicted examining the behaviours of individual parts and the laws governing their interactions (Johnson 2001; McDaniel and Driebe 2005).

Elements interacting in a complex system may change their behaviours and properties, co-evolving in order to adapt to each other and to their environment. Consequently, new patterns of organization emerge spontaneously without the intervention of a centralized control, and the system as a whole displays properties of self-organization and adaptation (McDaniel and Driebe 2005; Miller and Page 2007; Quinn Patton, 2010).

Interactions among elements in a complex system are usually non-linear. Depending on the state of the system, a given interaction can: develop according to different patterns; generate different outcomes; and trigger reactions and changes that transcend the initial scope of the interaction (McDaniel and Driebe 2005; Miller and Page 2007; Quinn Patton 2010).

Emergence, adaptation and non-linearity make of unpredictability a further important characteristic of complex systems. Although unpredictability makes processes and related outcomes non-fully-controllable and knowable in advance, it is not synonym of chaos and randomness, since complex systems as wholes tend to change in order to self-organize and adapt (McDaniel and Driebe 2005; Quinn Patton 2010).

From a player-centric perspective digital game systems can display different degrees of complexity. The perceived complexity of a game depends mainly on: the player's cognitive capacity; mechanistic systemic complicacy; proper systemic complexity.

The cognitive capacity of the player is defined by subjective skills and objective limits on human capacity for gathering and processing information. Subjective skill limitations can prevent players from finding and gathering information actually available in the game (e.g. limited exploratory skills may lead to missing pieces of information in a virtual crime scene). However skilled they are, players are constrained by the objectively limited capacity of the human working memory (Miller, 1994) (e.g. a game of chess appears to be complex, unpredictable and non-fully-controllable mainly because players cannot remember all the possible sequences of chessboard configurations). Ignorance originates from these issues, leading players to wrongly perceive complexity where there is simple complicacy, or even simplicity (Miller and Page, 2007).

Perceived complexity can also result from mechanistic design decisions, which allow designers to define the mechanics of the game events based on causal and stochastic rules, thus controlling the development of sequences of events based on predefined scripts. Through mechanistic complicacy designers can deliberately hide information, gradually revealing or changing aspects of the game system (e.g. new entities and behaviours, or unknown properties of already-known entities) depending on the fulfilment of predefined conditions or probabilistic events. Mechanistic complicacy could lead players to believe that global phenomena spontaneously emerge from local interactions of entities through uncertain and non-linear dynamics, whereas everything actually unfolds based on predefined criteria.

Finally, games can be designed as proper complex systems when interactions among players and system entities can result in consequences of a higher order. These consequences: change the state and behaviour of the game; lead to new discernible and rational organizations of the game system as a whole; and are not planned or even predicted by the game designers (Sweetser 2007). In this case, 'A modest number of rules applied again and again to a limited collection of objects leads to variety, novelty, and surprise. One can describe all the rules, but not necessarily all the products of the rules (…) which may arise from evolution.' (Campbell 1983, p. 127).

Mechanistic design decisions can involve the player in dynamics perceived as non-linear, requiring to deal with what Sweetser (2007) calls first and second order emergence. Even when a game unfolds based on predefined causal mechanics and scripts, local interactions could have effects on both the game elements immediately involved and nearby elements in the game world (first order emergence). Furthermore, preconceived causal mechanics can allow players to use basic elements of the game system to create strategies and solve problems in alternate ways (second order emergence). Finally, mechanistic decisions can allow for non-linear developments of game events, through non-linear game progression (e.g. multiple possible progression paths through different stages of a game). Hence, mechanistic design can generate dynamics requiring the player to face uncertainty, emergence and adapt to the unfolding of game events, almost as if the game were a proper complex system.

Systemic complexity is the only quality in a game that can require players to engage with what Sweetser (2007) calls third order emergence: changes on a global scale arising from dynamics happening at a local scale. Third order emergence can change salient traits of the game system as a whole, requiring players and other entities to change and adapt through repeated processes of self-organization (e.g. in a gaming world populated by intelligent agents organized in social systems, a sudden flooding could change the value of resources and social relationships, triggering processes of adaptation at both a local and global scale, and ultimately changing the winning strategies). In this case players have to deal with uncertainty, frequent change and ill-defined problems, and mastery and success are defined by the ability to adapt to change and facilitate the emergence of new favourable system organizations.

5. The study

5.3 Rationale

The challenging nature of sustainability is defined by the complex system dynamics originating from the interplay of the economic, environmental and social dimensions of our world (Elkington, 1999). Given its aims and nature, sustainability learning can be generally regarded as learning to cope with complexity in a specific domain and with specific aims (Tilbury 2004; Davis and Sumara 2006; Sipos, Battisti and Grimm 2008). Furthermore, educational research suggests that learning for complexity, intended as the ability to cope with complex systems, emerges as an adaptive response from the active and passive involvement of individuals in complex system dynamics (Figure 3).

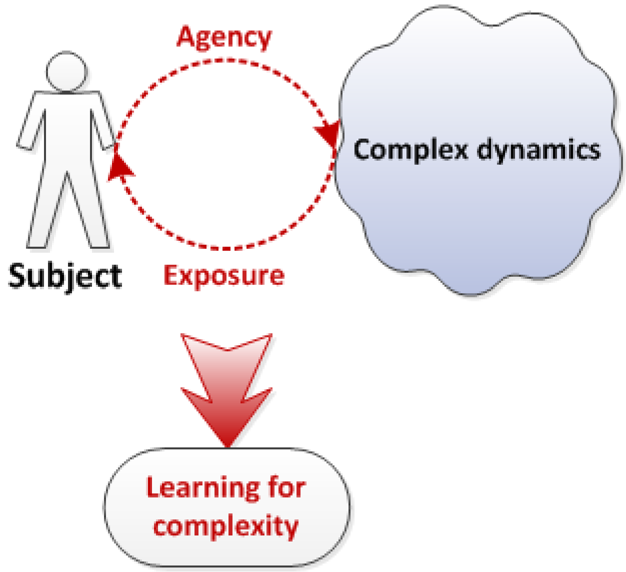

Figure 3: Emergence of learning for complexity

Consequently, we aimed this study at exploring how broadly available sustainability games facilitate the development of sustainable mindsets. In order to fulfil this aim we investigated game system aspects defining complex dynamics related to the development of properties of the sustainability mindset.

Our inquiry was driven by the following guiding questions:

- What types of games are being created?
- What is the target public?
- To what extent are sustainability-related topics addressed?
- To what extent are complex system dynamics leveraged by games?

We consequently investigated the following five categories of game aspects:

- Product profile: aspects related to the production process and outreach of the game
- Contextualisation: aspects defining the meaning and nature of game system dynamics
- Agency: aspects defining possibilities for the player to act upon and generate changes in the game system
- Sociality: aspects fostering purposeful social interactions among players
- Adaptivity: aspects promoting player proactive and/ or responsive adaptation to changes in the game environment

5.4 Games selection

The study analysed twenty games, selected based on their visibility on Google search engine. Only games directly appearing or being mentioned by third parties in the first five pages of the search results were chosen. This procedure was carried out in February 2011, which is important to consider as visibility in search engines changes in time. The search strings used were “Games AND sustainability” and “Games AND sustainable development”. Consequently, the search only yielded games in English.

We frequently found labelled as “games” series of activities and game-like applications that cannot be considered as proper games (e.g. a website to calculate own carbon footprint). These were not included in the analysis.

5.5 Data collection and analysis

Selected games were analysed either by playing them directly or by examining detailed information found in online sources. Time spent analysing each game was varied, depending on their goals and dynamics. Not all the games were completed, since some were open-ended games with no final winning condition, and others repeated game dynamics across different levels.

Data was gathered using a structured template describing the analytical criteria and procedure. The analysis was based on game elements allowing to study the contextualisation of the game and identify characteristics of systemic complexity in game dynamics. The template was structured in three parts:

1. **General information**, reporting:
   - Title
   - Creator of the game
   - Platform
   - Target age
   - Rating

2. **Contextualisation**, identifying and describing elements defining the impact of the setting, storyline and aims of the game on the definition of the meanings of game dynamics and their relationship with specific topics of sustainability. Elements analysed in this category mainly concerned:
   - Sustainability topics underlying the setting and storyline of the game.
   - Roles interpreted by the player and related motivations.
   - Relatedness of game aims with the domain of sustainability.

3. **Gameplay**, identifying and describing aspects of game dynamics related to complexity and the sustainability mindset. Elements analysed in this category concerned:
   - Game genre. Based on research on game genres (Fabricatore 2000b, Apperley 2006, Kim 2008) we classified games in categories differentiated by aspects of game dynamics potentially impacting the development of the sustainability mindset. We considered the following categories:
     i. Q&A (question and answer): games requiring players to answer questions relying on previously acquired knowledge in order to progress and/or earn credits/score. These games usually provide feedback promoting the understanding and memorisation of information.
     ii. Simulation: games focused on the simulation of the mechanics of some system (e.g. machinery, cities, ecosystems), requiring players to understand such mechanics in order to purposefully act upon the system.
     iii. Action-adventure: games involving players in interactive stories, requiring them to explore and interact with the environment in which they are immersed, solving problems and enigmas to contribute to the unfolding of the story. In this genre the degree in which action and narrative aspects are emphasised varies from game to game.
     iv. Strategy: games requiring planning skills in order to develop, administer and deploy limited resources in constrained conditions, in order to fulfil the purposes of the game.
     v. Puzzle: a form of game requiring players to configure a desired state (solution) employing different components (pieces). Puzzle games usually rely on objective rules determine whether a solution is correct or not, and/or compare solutions (e.g. a jigsaw, where pieces either fit with each other or not). However, it is possible that victory conditions are determined based on subjective rules (e.g. human judges comparing solutions to choose 'the best one').
   - Sociality
     i. In-game social interactions required/permitted by the game, and related communication infrastructures.
     ii. Affordances for game-related social interactions outside the game world.
   - Agency
     i. Possibilities of choosing roles and/or embracing alternative motivations corresponding to different play approaches.
     ii. Relatedness of gameplay activities with the domain of sustainability.
     iii. Scope of the game space (i.e. relation of material vs. virtual spaces in the game).
     iv. The nature of problem-solving activities involved in the game (i.e. exercises, well-defined or ill-defined problems).

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v. Definition of objectives (i.e. degree: amount of information provided to the player to define the objectives; timeliness: moment when such information is provided).
vi. Non-linearity of progression, procedures and aims in gameplay activities (i.e. to what extent players can define their path of progression, decide how to achieve game goals and/or which aims to fulfil).

- Adaptivity
  i. Emergence of local and global phenomena from local events, either triggered by the player or by the system.
  ii. Unpredictability of game events.

Data was analysed calculating frequencies for individual game characteristic. The chi-square test was used to evaluate the association between characteristics found in games.

6. Results

Figure 4 shows the distribution of games by country and genre. Most games analysed were developed in the UK (6), Australia (5) and the USA (4). Eight (40%) games were supported by sustainability organisations (e.g. institutions promoting education for sustainability); seven (35%) by companies offering public services (e.g. energy and communication); and three (15%) were games originating from private or independent efforts (e.g. students, scientific associations).

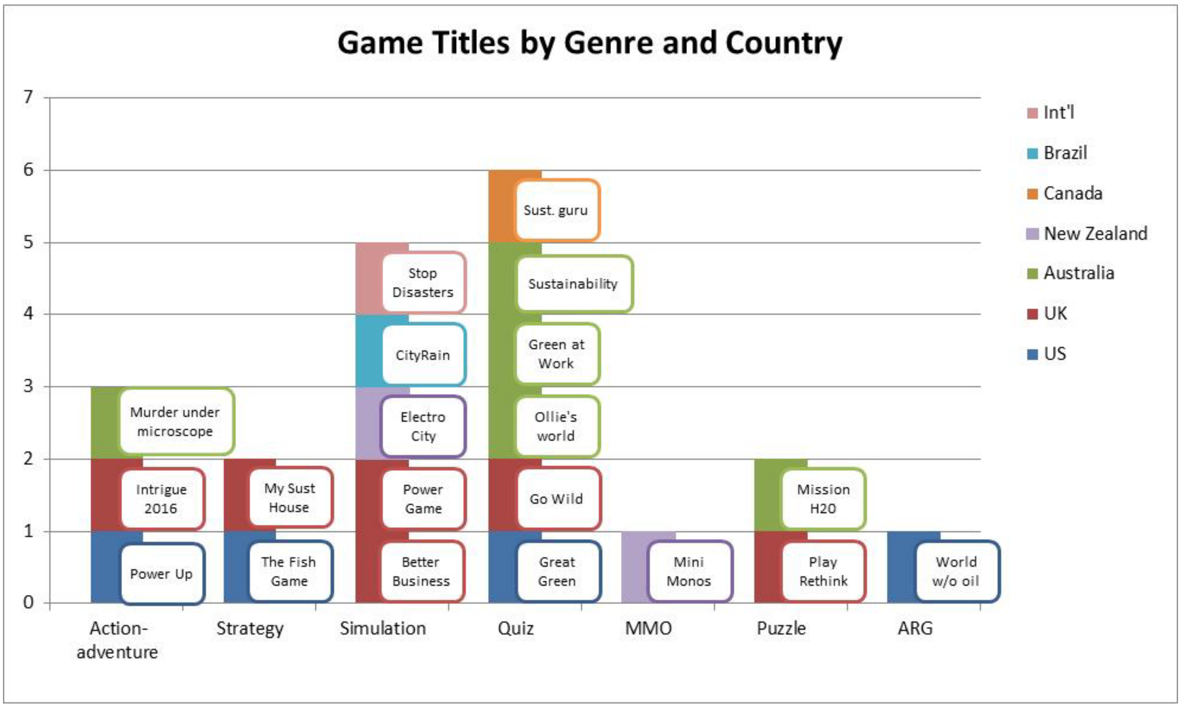

Figure 4: Games by country and genre

The two most commonly found game genres are quiz-like (30%) and simulation (25%) games. Most quiz-like games require players to answer questions regarding environmental issues to advance in the game, promoting knowledge learning through textboxes with brief explanations about the question topic. Simulation games analysed usually demand players to create and administer a city or village, requiring sustainable economic, environmental and demographic management. Other games in this category involve specific topics like water and energy management, and business decision making. Fifteen percent (3) are Action-adventure games. Two of them involve players in detective and mystery stories such as discovering who, when and how an environmentally-related crime was perpetrated. The other game invited the player to explore the game world to re-establish an eco-balance. Two (10%) strategy games were found. Game dynamics in these games involve planning how to make a living from fishing maximising income while keeping an appropriate number of fish in a lake, and planning policies to reduce gas emissions in a virtual world. Two puzzle games (10%) were found. Despite both games belong to the same genre, they are very different from each other. One game requires players to sort elements according to their characteristics, within a certain time limit. The other game is a multiplayer non-digital game in which players have to draw objects satisfying certain recycling conditions, and winner is proclaimed by the whole group of players. We found one Massive Multiplayer Online game (MMO) in which players can freely explore and engage in different individual and collective activities (e.g. recycling). We also found one Alternate Reality Game (ARG) in which real and virtual spaces were combined to develop a fiction about an environmental crisis based upon players' interventions.

Games have different target publics, although a significant proportion is oriented to children. 40% (8) are specifically created to be integrated in schools, usually complemented with supporting materials on how to use them in the classroom and/or combined with other educational activities. Two games (10%) are for pre-school and primary school-age children, requiring adult involvement or supervision. Two games were specifically oriented to adults (e.g. workplace-related games). 40% of the games have an unspecified target age.

The dimensions of sustainability are unevenly emphasised by games (Figure 5). The environmental dimension is present in all the games analysed. 35% of games include only topics regarding this dimension (e.g. energy efficiency, waste management, conservation of natural resources, gas emissions reduction). The same number of games deals with environmental and economic development (e.g. sustainable production and consumption). The remaining 30% of the games combine environmental, economic and social aspects (e.g. combining environmental and economic themes with demographics and development of human capacity and skills).

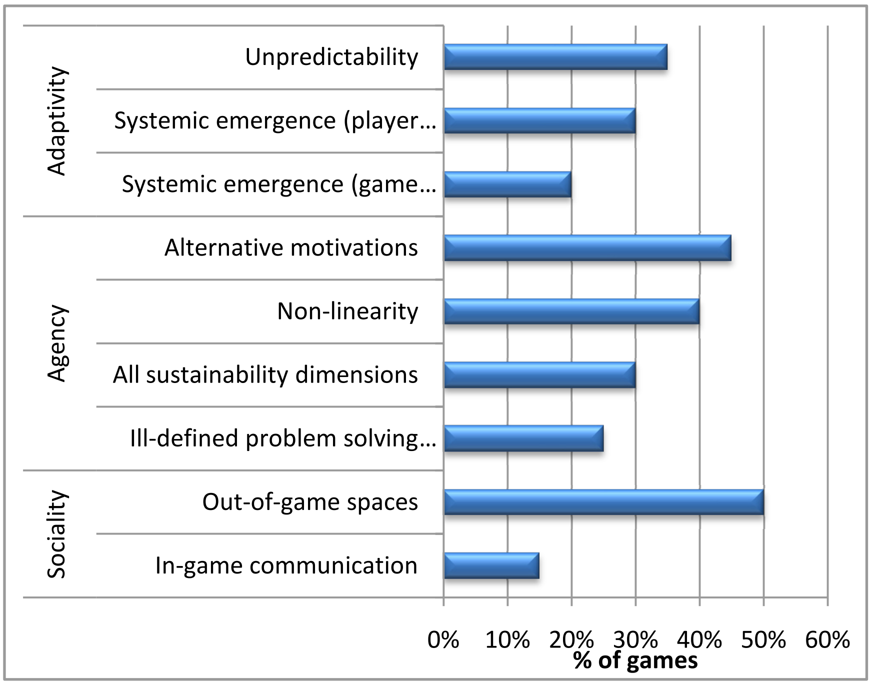

Figure 5: Sociality, agency and adaptivity traits in games

Game objectives are usually well-defined and are presented at the beginning of the game (55%). Few games (25%) have ill-defined goals, requiring the player to analyse and discover information during game play to better define the objectives. 20% of games present a combination of well and ill-defined goals, providing to players one or two explicit goals while requiring them to formulate new ones as they advance in the game.

The nature of problem-solving activities that players face during game play is variable. 35% of the problems have an exercise structure, requiring the application of previously acquired knowledge and skills (e.g. quiz and puzzle games). Notably, most games presenting this type of problems are targeted to children. 40% are well-defined problems with a finite number of possible solutions, requiring investigation as the solution is not immediately visible to the player (e.g. a mystery game). 25% of the games analysed present ill-defined problems. They have an undefined number of possible solutions and thus no algorithm can be used to solve them. Solutions emerge throughout the resolution process, allowing the exploration of multiple strategies.

We analysed the possibilities to develop social skills and collectively engage players in the pursuit of common goals by investigating the affordances for social interaction in in-game and out-of-game spaces. We found that the vast majority of the games (75%) are single-player, thus not providing an in-game space for social exchange. We observed that 50% of the games offer players out-of-game spaces to share game-related experiences and information (e.g. the presence of a game community; dedicated websites and blogs). Three games (15%) provide players with in-game communication tools (e.g. chat, posting). Among the multi-player games, three exploit competition dynamics, one combines competitive and collaborative dynamics and one is a collaborative-only game. One game strongly relies on collective efforts and multiple perspectives to manage a global crisis.

Opportunities for choosing roles and/or embracing alternative motivations corresponding to different play approaches are present in 45% of the games analysed. These opportunities are not always explicitly offered to players, and they become evident as players advance in the game or play different matches. For example, in one of the games the player has to manage a company trying to keep a balance between the company's production and profit, environmental impact, labour union demands and social welfare. As the player advances, she realises that the game can be played using different approaches to achieve alternative successful balances of outcomes.

Non-linearity, found in 40% of the games, refers to both non-linearity of progression and procedures. The cases we found of progression non-linearity in general provide the possibility to choose when to complete sub-goals (e.g. building a hospital can be done before or after educating the general population to face a natural disaster). Procedural non-linearity is clearly appreciated in city management games in which players can choose the type of buildings to build (e.g. hospitals, schools, home apartments) to promote social sustainable development.

Opportunities for the player to face unpredictable situations are present in 35% of the games. Random events like earthquakes or economic crises while building a city are good examples of unpredictable situations that players face in the games that we analysed.

Systemic emergence is the complexity trait less frequently found in the games analysed. Player-triggered emergence is present in six games (30%), requiring players to deal with systemic dynamics triggered by their presence and/or decisions in the game. Examples of this type of emergence include the demographic change due to water management decisions taken by player. Game-triggered systemic emergence was found in four games (20%). This characteristic is almost always present in multiplayer games, in which the presence of other players determines changes in the game world without the direct participation of the player's own personal decisions or actions. A good example of this kind of emergence is found in the ARG game, in which the game evolves according to the input of many players trying to face an energy crisis.

In general, there is a tendency for complexity properties to appear in simulation, ARG and MMO games, although it is not possible to numerically verify this due to the insufficient number of games analysed belonging to each game genre.

Chi-square analyses show that games which deal with the three dimensions of sustainability tend to present more unpredictability ($X2(2, N=20)=5.88$, $p=0.05$), process non-linearity ($X2(2, N=20)=9.39$, $p=0.01$), and a preponderance of ill-defined problems ($X2(4, N=20)=6.41$, $p=0.03$) and player-triggered emergence ($X2(2, N=20)=6.85$, $p=0.03$). Although not statistically significant, the analysis shows that 80% of games treating the three pillars of sustainability are not specifically targeted to children. Most of the games designed for young populations present only environmental topics.

The preponderant type of problem-solving activities presented to the players appears to be associated to different game characteristics that would promote a sustainable mindset. Compared to games relying on exercises and well-defined problems, games presenting ill-defined activities offer to players: more possibilities of exploring different perspectives, roles and/or motivations ($X2(2,N=20)=11.92$, $p=0.00$); more opportunities to face unpredictability ($X2(2, N=20)=8.24$, $p=0.02$); a higher contextualisation of gameplay activities, favouring meaning making ($X2(2, N=20)=16.67$, $p=0.00$); and higher process non-linearity ($X2(2, N=20)=8.33$, $p=0.02$). Systemic emergence, both player and game triggered, are found more frequently in games presenting ill-defined problems (X2(2, N=20)=12.86, p=0.00 and X2(2, N=20)=7.03, p=0.03 respectively).

7. Discussion

Our results suggest that broadly available sustainability games are generally focused on environmental topics and/or targeted to children. The idea of “using games to educate children about the environment” seems to be the ultimate synthesis of the frequent associations between “games and children”, “children and caring for environment” and “education and children”. Focusing mainly on children and environmental contents may lead to neglecting the potentialities that games can offer concerning target ages and integration of contents.

As to age, “learning for sustainability” is as important for children as it is for adults (UNESCO 2005), who currently constitute the majority of gamers (ESA 2010). Furthermore, games with an unspecified target age group usually rely on age-neutral dynamics and contents to attract a broad spectrum of players. We believe that it is important to create true multi-age games, integrating varieties of age-specific elements designed to appeal players of different ages, and fostering interaction and collaboration across different age groups.

As to contents, most of the analysed games address the three main pillars of sustainability unevenly, particularly overlooking the social dimension (e.g. poverty reduction and social equity). The challenges of sustainability originate from the interplay between social, environmental and economic elements. Hence, the lack of integration of the three core sustainability themes seems somewhat contradictory with the holistic nature and aims of learning for sustainability (Elkington 1999; Tilbury 2004; Sipos et al. 2008). Furthermore, the associations that we studied suggest that games based on settings integrating the three core themes of sustainability are also the most reliant on ill-defined problem-solving. The presence of ill-defined problem-solving activities, in turn, seems associated with further elements key to fostering sustainability learning (e.g. non-linearity, unpredictability and emergence). Hence, we believe that game settings based on the integration of the social, economic and environmental dimensions of sustainability could offer to game/instructional designers better possibilities for the creation and contextualisation of gameplay dynamics appropriate to promote and facilitate situated and deep sustainability learning. In addition, we believe that the interplay between the three dimensions would also enhance the entertainment value offered to players, as this interplay is already key to massively successful leisure games appreciated by millions of users worldwide (e.g. FarmVille, CityVille and SimCity).

We found that many games examined rely on educational approaches emphasising the dissemination of knowledge regarding environmental education. Furthermore, approximately one third of the games rely on Q&A dynamics, fostering decontextualised knowledge acquisition and the development of basic cognitive skills. This indicates a focus on embedding traditional learning contents and activities in ludic contexts, rather than leveraging learning processes properly contextualised in gameplay dynamics. This approach may lead to the creation of overly education-centred products which neglect aspects fundamental to making games fun and engaging. Sustainability games should be entertaining, so that players feel motivated to play them even outside formal educational settings. We believe that the potential of game-based learning would be fully exploited by designing intrinsically motivating games, engendering dynamics that naturally require situated, sustainability-relevant learning.

Approximately three quarters of the sustainability games analysed require players to face problems and pursue goals which are well defined. This is somewhat discrepant with educational research indicating that the ability to deal with ill-defined problems and emerging objectives is key to the development of mindsets capable to deal with complex systems and sustainability (Tilbury 2004; Tilbury & Wortman 2004; Davis and Sumara 2006; Bloom 2010).

Approximately three quarters of the games analysed are single-player, thus precluding any form of in-game player-to-player interaction. This suggests that designers frequently conceive games as individual experiences, regardless of their educational aims. Social interactions are fundamental to engage in complex dynamics involving other human beings. Learning in complex systems can be considered a trans-level process, unfolding through the interplay between individual and collective understandings emerging from and feeding back into each other, in a continuous process of adaptive

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evolution (Davis and Sumara 2006). Hence, we believe that the integration of social interactions in gameplay dynamics benefits the overall learning value of sustainability games. It is worth noting that approximately half of the games analysed were complemented by facilities promoting out-of-game interactions within game communities. Out-of-game communities represent a good possibility of promoting game-related social interactions (Steinkhueler 2008). However, based on the nature and success of game communities in the case of social and MMO leisure games (e.g. Farmville and World of Warcraft) we believe that the potential of game communities can be better leveraged if communal interactions are actually driven by social interactions within the game.

Our findings indicate that key game dynamics aspects fostering adaptivity (e.g. emergence and unpredictability) are rarely harnessed (the most present of these aspects – unpredictability – is integrated in only 35% of the games). This might be detrimental to the development of the sustainability mindset, considering that to facilitate complex learning learners should be involved as much as possible in complex dynamics (Davis and Sumara 2006).

In conclusion, our exploratory study suggests that games can indeed provide key conditions and opportunities to foster sustainability learning. When designed with complexity in mind, games are most suitable to promote the development of complex systems thinking and facilitate a systemic understanding of sustainability. However, complex system dynamics and integrated contextualisations are not as common as we would have expected, given the educational aims of the games analysed. Further studies are needed to determine whether what we observed are general problems or simply issues incidental to the games we studied. However, at the moment there seems to be large space for improvements oriented at creating more 'complexified' game systems through a better leveraging and integration of non-linearity, emergence, uncertainty, ill-defined problems and social interactions, and requiring players to address issues from multiple perspectives.

Finally, we believe that efforts should also be made to enhance the accessibility of sustainability games, addressing issues such as language, specific user needs (e.g. disabilities), geopolitical barriers and access to technology. This is essential to maximise the outreach of the benefits of gaming for sustainability.

References

Apperley, T. H. (2006) "Genre and game studies: Toward a critical approach to video game genres", *Simulation Gaming*, vol. 37, no. 1, pp. 6-23.

Avedon, E. M. (1971) "The Structural Elements of Games". In: Avedon, E. M. and Sutton Smith, B. (eds) *The Study of Games*, pp.419-426. New York: John Wiley and Sons, Inc.

Becker, K. (2007) "Pedagogy in commercial video games" in Gibson, D., Aldrich, C. & Prensky, M. (eds.) *Games and simulations in online learning: Research and development frameworks*, Hershey, PA: Information Science Publishing.

Bloom, J. (2010) "Systems Thinking, Pattern Thinking, and Abductive Thinking as the Key Elements of Complex Learning". Paper presented at the *Annual Meeting of the American Educational Research Association (AERA)*. Denver, CO: AERA. [online] Available at: <http://www.jeffbloom.net/docs/Bloom-Paper-AERA2010.pdf> [Accessed 23/02/2012].

Campbell, J. (1983) *Grammatical Man: Information, Entropy, Language, and Life*. New York: Simon & Schuster.

Davis, B. & Sumara, D. (2006) *Complexity and Education: Inquiries into Learning, Teaching and Research*. Mahawah, NJ & London: Lawrence Erlbaum Associates.

Dickey, M. (2005) "Engaging by design: How engagement strategies in popular computer and video games can inform instructional design", *Educational Technology Research and Development*, vol.53, no.2, pp.67-83.

Dieleman, H. and Huisingh, D. (2006) "Games by which to learn and teach about sustainable development: exploring the relevance of games and experiential learning for sustainability". *Journal of Cleaner Production,* vol.14, no.9-11, pp.837-847.

Elkington, J. (1999) *Cannibals with Forks: Triple Bottom Line of 21st Century Business*. Oxford: Capstone.

Elkington, J. (2004) "Enter the Triple Bottom Line". In: Henriques, A. and Richardson, J. (eds) *The Triple Bottom Line*. London: Earthscan.

ESA (2010) *2010 Essential Facts about the Computer and Video Game Industry*. [online] Available at: <http://www.theesa.com/facts/pdfs/ESA_Essential_Facts_2010.PDF> [Accessed 05/02/2012].

Fabricatore, C. (2000a). "Learning and videogames: An unexploited synergy", Working paper for the *AECT conference*. California. [online] Available at: <http://www.learndev.org/dl/FabricatoreAECT2000.PDF> [Accessed 18/05/2011].

Fabricatore, C. (2000b) “Playability in action videogames: a theoretical design reference”, PhD Thesis, Catholic University of Chile.

Fabricatore, C. (2007) “Gameplay and game mechanics design: a key to quality in videogames”. In *Proceedings of OECD-CERI Expert Meeting on Videogames and Education*, Santiago de Chile, Chile, 2007. [online] Available at: <http://www.oecd.org/dataoecd/44/17/39414829.pdf> [Accessed 05/02/2012].

Fabricatore, C. and López, X. (2009) “The impact of digital gaming on the development of the scientific mind”, Seminar held at the *Third Advanced International Colloquium on Building the Scientific Mind*, Cairo, Egypt, May 10-14.

Fabricatore, C., Nussbaum, M. and Rosas, R. (2002) ‘Playability in Action Videogames: A Qualitative Design Model’. *Human-Computer Interaction*, vol. 17, no.4, pp.311-368.

Gardiner, R. (2002) EARTH SUMMIT 2002 Explained. [online] Available at: <http://www.earthsummit2002.org/Es2002.pdf> [Accessed 05/02/2012].

Gee, J.P. (2007) *What video games have to teach us about learning and literacy* (2nd ed.), New York: Palgrave/Macmillan.

Harris, J. (2000) “Basic Principles of Sustainable Development”, Working Paper 00-04, Tufts University. [online] Available at: <http://ase.tufts.edu/gdae/publications/working_papers/Sustainable%20Development.pdf> [Accessed 05/02/2012].

Johnson, S. (2001) *Emergence*. London, UK: Penguin Books.

Juul, J. (2002) “The Open and the Closed: Games of Emergence and Games of Progression”. In: Mäyrä, F. (ed) *Proceedings of Computer Games and Digital Cultures Conference*. Tampere: Tampere University Press.

Kim, S. (2008) “What is a Puzzle?”, in Fullerton, T. (ed.) *Game Design Workshop: A Playcentric Approach to Creating Innovative Games*, pp. 35-39, Burlington, MA: Morgan Kaufmann Publishers.

López, X. (2010) *Videogiochiamo dunque impariamo? Un modello per l’analisi educativa dei videogiochi*. Published PhD dissertation, Roma Tre University, Rome: Edizioni Nuova Cultura.

Malone, T. and Lepper, M. (1987), “Making Learning Fun: A Taxonomy of Intrinsic Motivations for Learning”, in Snow,R. & Farr,M. (eds.) *Aptitute, Learning and Instruction: III. Conative and affective process analyses*, Hilsdale, NJ: Erlbaum.

McDaniel, Jr., R. R. and Driebe, D. J. (2005) “Uncertainty and Surprise: and Introduction”. In McDaniel, Jr., R. R. and Driebe, D. J. (eds.) *Uncertainty and Surprise in Complex Systems*, pp.3-11. Heildelberg: Springer-Verlag.

Meadows, D. H. (2009) *Thinking in Systems: A Primer*. London: Earthscan.

Miller, G. A. (1994) “The magical number seven, plus or minus two: Some limits on our capacity for processing information”, *Psychological Review*, vol.101, no.2, pp.343-352.

Miller, J. H. and Page, S. E. (2007) *Complex Adaptive Systems. An Introduction to Computational Models of Social Life*. Princeton, NJ: Princeton University Press.

Newell, C. (2008) “The class as a learning entity (complex adaptive system): An idea from complexity science and educational research”. *SFU Educational Review*, vol. 2 no. 1, pp. 5-17.

Patton, M. Q. (2010) *Developmental Evaluation: Applying Complexity Concepts to Enhance Innovation and Use*. New York, NY: Guilford Press.

Salen, K. and Zimmerman, E. (2003) *Rules of Play: Game Design Fundamentals*. Cambridge, MA: MIT Press.

Sipos, Y., Battisti, B. and Grimm, K. (2008) “Achieving transformative sustainability learning: engaging head, hands and heart”, *International Journal of Sustainability in Higher Education*,

Steinkuehler, C. (2008) “Cognition and literacy in massively multiplayer online games”, in Coiro,J., Knobel,M., Lankshear,C. & Leu,D. (eds.), *Handbook of Research on New Literacies*, Mahwah, NJ: Erlbaum.

Svoboda, S. and Whalen, J. (2004) “Using experiential *simulation* to teach sustainability”, *Greener Management International*, 48(Winter), pp.57-65.

Sweetser, P. (2008) *Complexity in Games*. Boston, MA: Charles River Media.

Tilbury, D. (2004) “Rising to the Challenge: Education for Sustainability in Australia”, *Australian Journal of Environmental Education*, vol.20, no.2, pp.103-114.

Tilbury, D. and Wortman, D. (2004) *Engaging people in sustainability*, Cambridge, UK: IUCN.

UN (2002) *Sustainability not ‘a pious invocation’ but a ‘call to concrete action’*, [press release], 05 March 2002. [online] Available at: <http://www.un.org/News/Press/docs/2002/sgsm8150.doc.htm> [Accessed 05/02/2012].

UNESCO (2005) *The DESD at a glance*. [online] Available at: <http://unesdoc.unesco.org/images/0014/001416/141629e.pdf> [Accessed 05/02/2012].

UNWCED (1987) *Our Common Future* (The Brundtland Report). Oxford: Oxford University Press.