A Model to Identify Affordances for Game-Based Sustainability Learning

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Abstract
Sustainability learning requires the assimilation of domain-specific knowledge and the development of mindsets suitable to engage in complex system dynamics to foster sustainable action. There is a need for bespoke educational models and practical tools to foster sustainability learning. Digital games can answer such need, due to their remarkable potential to wholly engage players in sustainability-related contexts and problems entailing complex dynamics, and the advantages of intrinsically motivating game-based learning processes. However, there is evidence suggesting that such potential might be underexploited. To address this, in this paper we present a model for the identification and analysis of game-based sustainability learning affordances. Our model can be used to support the selection of games for educational purposes, or to facilitate the planning and introduction of game-based sustainability learning affordances when designing new games.

Keywords: game-based learning, model of affordances, sustainability, complexity.

1. Introduction

Sustainability is a constantly evolving concept (UNESCO 2005), commonly regarded as "(...) development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43). Sustainability involves multiple fields and perspectives, integrating the environmental, economic and social dimensions (Tilbury & Wortman 2004; UNESCO 2005). The interplay of these tightly coupled dimensions originates global dynamics and changes that cannot be fully predicted or explained based on local events, thus making sustainability a complex phenomenon.
The sustainability ethos requires individuals and societies to embrace developmental models viewing the Earth as a single, global community, with a common future that depends on protecting environment and shared human interests above and beyond market interests (UNESCO 2005). Accordingly, bespoke educational policies and frameworks are needed to foster sustainability learning, enabling individuals and societies to change unsustainable developmental models (Tilbury & Wortman 2004; UNESCO 2005).

1.1 Sustainability learning

Alongside the assimilation of domain-specific knowledge, sustainability learning requires developing mindsets suitable to engage cognitively, affectively and operationally, and deal with dynamic properties of complex systems to foster sustainable action (Tilbury & Wortman 2004; Espinosa & Porter 2011). In our past work (Fabricatore & López 2012) we identified key characteristics of such mindsets (Figure 1).

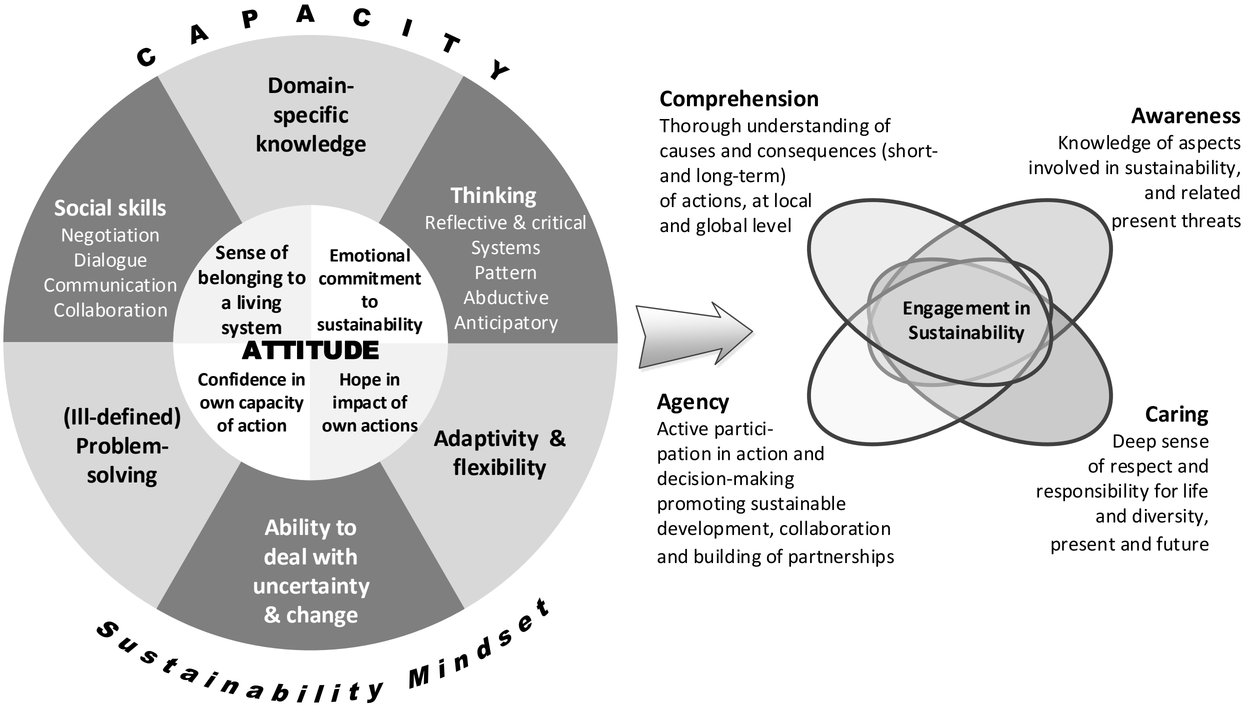

Figure 1. Sustainability mindset and engagement in sustainability

Sustainability learning requires: engaging learners in problems and contexts associated with key sustainability values and concepts (UNESCO 2005; Tilbury & Wortman 2004; Dieleman & Huising 2006); exposing them to complexity traits eliciting the characteristics of the sustainability mindsets (Espinosa & Porter 2011; Fabricatore & López 2012); and promoting learning as an adaptive response to complex environmental dynamics (Davis & Sumara 2006; Espinosa & Porter 2011). Davis and Sumara (2006) identified specific conditions promoting this type of learning:

i. *Peer interaction*, fostering the interplay between individual and collective learning.
ii. *Common understandings and language*, allowing meaningful peer interaction.
iii. *Heterogeneity of perspectives*, fostering diverse reactions to environmental change.
iv. *Decentralised control*, fostering individual and collective decision-making and interactions.
v. *Enabling constraints*, functioning as rules guaranteeing coherency through minimal restrictions.
vi. *Randomness and disruptions*, engendering unanticipated possibilities eliciting adaptation.

There is a strong need of both theoretically solid and empirically relevant educational models and tools to facilitate sustainability learning (Tilbury & Wortman 2004; UNESCO 2005; Dieleman & Huisingh 2006). Digital games can be an answer to such need.

1.2 Digital games to foster sustainability learning

Digital games are systems in which players engage in activities to fulfil overarching aims, interacting with each other and/or artefacts, based on mechanics defined by game rules (Salen & Zimmerman 2003; Fabricatore 2007). Gameplay activities are processes whose completion generates accountable outcomes relevant to progress in the game. They can be regarded as problem-solving activities, since they require players to generate transitions from ‘current’ game states to ‘desirable’ goal states described by activity objectives (Zeitz 2006; Schell 2008). Gameplay activities are framed by a context defined by interrelated conditions in which play happens. Through integrating game aims, state information, settings, themes and/or storylines, the context allows players to fully define/understand the meaning of gameplay activities (Gee 2007; Schell 2008).
Contextualised gameplay activities generate situated experiential learning processes that motivate players (Dieleman & Huising 2006; Fabricatore 2007; Gee 2007; López 2010). Since game challenges often require players to learn about essential game elements and develop skills needed to succeed, there is an intrinsic connection between fun and learning in games, making learning crucial to wholly engage players in games, cognitivively, operationally and affectively (Fabricatore 2007; Gee 2007; López 2010; Fabricatore & López 2012).

Depending on the involved mechanics, artefacts, and the underpinning problems, gameplay activities can engender different traits of complexity (Fabricatore & López 2012). Integrating perspectives from complexity sciences (McDaniel & Driebe 2005; Miller & Page 2007), complexity and learning (Davis & Sumara 2006; Espinosa & Porter 2011), and game studies (Salen & Zimmerman 2003; Fabricatore 2007; Sweetser 2008; Fabricatore & López 2012), we identified core complexity traits which affect learning in complex systems and can be found in games:

i. *Emergence*, defined by the onset of system properties and organised behaviours which: arise from the interaction of system components; do not belong to any of the interacting components alone; cannot be explained as a linear superposition of properties and/or behaviours of the components.
ii. *Uncertainty*, defined by the impossibility of fully predicting and/or controlling processes and related outcomes.
iii. *Non-linearity*, defined by interactions among system elements which, depending on the context, can: develop according to different patterns; generate different outcomes; generate effects transcending the initial scope of the interaction; and cannot be explained in terms of cause-effect rules.
iv. *Self-organised adaptive evolution*, defined by the ability of system components to change their properties and/or behaviours in order to adapt to changes, without the intervention of a centralised control.
v. *Dynamic coupling*, defined by the ability of system components to interconnect and interoperate depending on contextual factors.

Digital games present remarkable potentialities to foster sustainability learning, because of the benefits of learning through game-playing, and the possibility of leveraging virtual worlds to engage players in sustainability-related contexts and problems entailing complexity traits. However, through our past research we found that these potentialities are not always fully leveraged, even in games specifically aimed at sustainability education (Fabricatore & López 2012).

In this context, our research aimed at formulating a model to facilitate the identification and analysis of sustainability game-based learning affordances, in order to enhance the leveraging of digital games to foster sustainability learning.

2. Method

Our model was extrapolated through an iterative process of analysis, open and axial coding (Strauss & Corbin 2008) of the contents of 30 games. We analysed in each game:

- Gameplay activities: dynamics; objectives; mechanics; artefacts; underpinning problems (focussing on initial state, goal state, possible solution approaches, constraints and information definition throughout the activity); and relationships between activities.
- Context: setting, storyline, themes and overarching game aims.

We defined affordances as aspects of game elements generating possibilities for sustainability learning to happen (Gibson 1977). Consequently, we sought game aspects fulfilling one or more of the following criteria:

i. Contextualise game system dynamics in situations related to sustainability.
ii. Engender traits of complexity.
iii. Facilitate learning as an adaptive response to complex dynamics.

20 sustainability games and 10 leisure games were analysed. Sustainability games were selected based on their visibility on Google search engine in February 2011 (search strings used: “Games AND sustainability” and “Games AND ‘Sustainable Development’”). Only games referenced in the first five pages of the search results were chosen. These criteria were still fulfilled by 70% of the selected games in March 2014. Leisure games were selected in November 2013, based on their potentiality to fulfil the selection criteria (ascertained through on-line reviews and descriptions). Only games in English were included in the sample.

Both authors analysed the games through personal play experience, playing them until completed, or until all available types of core gameplay activities and related contextual aspects were explored. Types of gameplay activities were identified directly through game-play, based on game aims, objectives and progress feedback, or beforehand, through on-line reviews and tutorials.

3. Results

We identified four categories of game-based learning affordances fulfilling our selection criteria.

3.1 Sustainability contextualisation

Sustainability contextualisation affordances determine the extent to which the meanings of player activities are relevant to, coherent with and driven by sustainability elements and values. Contextualisation can enhance the situatedness and authenticity of sustainability-relevant game-based learning, eliciting player understanding of and engagement in sustainability, and facilitating the transfer of game-based learning to non-game-based contexts (Dieleman & Huising 2006).

3.1.1 Thematic contextualisation

The aims, storylines, settings and themes within the game context are based on unifying ideas key to environmental, economic and/or social sustainability. Consequently, players' meaning-making processes are explicitly framed by sustainability, and in order to pursue aims they care about, players are required to understand and act based upon sustainability principles and values.
Example. The theme of the game is enterprise management in a modern-times setting, and the game is aimed at sustainable enterprise development, balancing the needs of generating profits, avoiding negative impacts on the environment, the social community and the global economy (environmental, economic and social sustainability thematic contextualisation).

3.1.2 Gameplay contextualisation

The operational objectives of core gameplay activities, their underpinning problems and/or the involved gameplay mechanics relate to the domain of sustainability, requiring players to explore and understand conditions, problems and/or mechanics relevant to operate in sustainability contexts. Operational objectives are intended as concrete outcomes required to fulfil the purpose of gameplay activities. Operational contextualisation could require players to pursue objectives and engage in learning relevant to sustainability even if the purposes of gameplay activities and/or the overarching game aims are not openly related to sustainability.
Example. The game requires farming (problems, mechanics and objectives related to environmental sustainability) to generate resources required to expand a kingdom (non-sustainability-focussed aims).

3.1.3 *Multiplicity of overarching sustainability game aims*

Players can succeed through pursuing multiple alternative and/or complementary sustainability-related aims. Thus, players must embrace different perspectives to understand and evaluate meanings, implications and relationships of aims.
Example. Players must plan the development of a city pursuing a balanced combination of growth, satisfaction of people, budget administration, energy supply, and environmental impact.

3.1.4 Hybrid real/virtual context

The game context integrates real-world and virtual-world elements, requiring players to think "across" fiction and reality. Real-world elements are intended as concrete entities (e.g. places, persons, objects, etc.), not mere concepts (e.g. social sustainability).
Example. Players investigate environmental crimes set in a virtual world, relying on information gathered in the real world through studying real environmental issues.

3.1.5 Player actor contextualisation

The player embodiment in the game world has a role coherent with and relevant to the domain and values of sustainability, and its representation benefits player immersion in the game context.
Example. The player interprets a farmer in a Third-World country, and has to farm in adverse conditions to feed poor families (sustainability-contextualised player actor).

3.2 Agency

Agency affordances determine the nature of the gameplay problems driving player action, and the extent to which players can exert control on the game system and act unconstrainedly, alone or in groups. Agency affordances affect player engagement in complexity defining possibilities to plan and execute interactions with the environment in different ways, and modify plans based on players' evolving thinking, possibly in reaction to unanticipated emergent conditions (Miller & Page 2007; Beinhocker 2013). Agency affordances can also affect player engagement in complexity through defining the amount and nature of information available to players to tackle gameplay problems, and the possible approaches to problem-solution. The extent to which players can modify the state of the game world at their own will enhances control decentralisation, promoting non-linear gameplay dynamics and heterogeneous player reactions to environmental changes, and consequently fostering learning in conditions of complexity (Davis & Sumara 2006). Through eliciting the exploration of possibilities, agency affordances require complexity-savvy thinking skills (Bloom 2010).

3.2.1 Multiplicity of player actors

Players can choose different actors, embodying different roles and relying on different in-game skillsets and resources. This requires players to evaluate and select different gameplay approaches, exploring alternative ways to fulfil the overarching game aims.
Example. In order to develop an eco-village, the player acts as a fisherman or a merchant, thus being responsible, respectively, for the provision of food for the village through sustainable fishing strategies, or for the balanced distribution of wealth through a sustainable management of market dynamics.

3.2.2 Definition of gameplay problems

The player engages in gameplay problems presenting aspects of ill-definition. The definition of problems affects player engagement in complexity through determining the extent to which players can/must explore different gameplay approaches, and/or make decisions and act based upon incomplete information, reviewing their approaches as new information emerges. Accordingly, gameplay problems can be classed as (Zeitz 2006):

i. *Exercise:* the solution to the problem is immediately visible; challenges come from players being required to apply pre-acquired skills and knowledge.
ii. *Well-defined:* how to achieve the goal state (i.e. the solution) is not immediately visible, requiring investigation; the initial state is well-defined by conditions valid when the player engages in the problem-solving activity; the goal state is well-defined through a set of conditions to be satisfied; there is a finite number of possible solutions; each solution can be structured as an algorithm of clear steps.
iii. *Ill-defined problem*: the initial and/or goal state cannot be clearly defined; the number of possible solutions is undefined; solutions cannot be shaped as algorithms; valid solution approaches emerge and are shaped throughout the gameplay activity process.

Example. The player has to develop cities, can do it in different ways, and is subject to evaluations (and possible penalizations) from a worldwide environmental protection agency (ill-defined problem).

3.2.3 Type of problem-solving approaches

Approaches required to solve gameplay problems elicit thinking strategies and skills compliant with complexity. Problem-solving approaches can be classed as (Weaver 1948):

i. *Analytical-descriptive:* analytical strategies involving collection, description and observation of concurrent and apparently correlated evidence.
ii. *Analytical-stochastic*: analytical methods studying average systemic behaviours and properties based on probability theory and statistical mechanics.
iii. *Holistic-adaptive*: empirical approaches studying relationships, combining different perspectives on the same phenomenon to understand what needs to be done and when.

Analytical-stochastic and holistic-adaptive approaches enhance players/learners complexity-savviness through requiring systems, abductive and pattern thinking in conditions of incomplete and/or uncertain information (Bloom 2010).
Example. The player has to develop a city maximising citizen satisfaction and dealing with conflictive interests like tax-paying, energy availability, and urban cleanness and greenness (holistic-adaptive approach, requiring new decisions to be made based on the analysis of the impacts of past decisions).

3.2.4 Player-governed non-linearity

Instead following pre-defined courses of action, players can define alternative plans to fulfil game aims, through leveraging:

i. *Procedural non-linearity:* players can define custom strategies to achieve a given objective.
ii. *Non-linear progression:* players can decide the order in which to accomplish game objectives.

Example. In order to protect people from wild fires, players can plan different ways to restructure urban centres, remove dried vegetation and plant fire-resistant vegetation with a limited budget (procedural non-linearity), and can freely decide when to do each task, within a maximum time-frame (non-linear progression).

3.2.5 Multiplicity of success objectives

Success in the game can be pursued through accomplishing different, alternative objectives, requiring players to adopt different worldviews to choose which objectives to achieve.
Success objectives are sets of concrete conditions defined by design that must be achieved to fulfil the overarching game aims. Their nature characterise games as:

- *i.* *Open-ended:* there is no conclusive victory game state, and overarching game aims must be continuously fulfilled through succeeding in the available gameplay activities.
- *ii.* *Single-victory-state:* there is a single conclusive victory state, which must be achieved through fulfilling a given combination of success objectives.
- iii. *Multiple-victory-states:* there are alternative victory states, associated to alternative combinations of success objectives.

Example. To contribute to the development of his town, the player must choose whether to be a farmer, developing and implementing efficient cultivation strategies to ensure sufficient crops while preserving water reserves; or an entrepreneur, maximising profit while adopting fair-trade strategies and creating sufficient wealth for the town (multiple-victory-state).

3.2.6 Hybrid real/virtual activities

Gameplay activities take place in both the real and virtual world, integrating real and fictional elements. This requires players to link fictional and real scenarios, transferring learned thinking skills across them.
Example. The player must gather information regarding environmental issues in the real world to deal with environmental crimes in a virtual world.

3.2.7 Context co-authorship

Player actions can alter the narrative and setting of the game context. Thus, meanings of future player actions may originate from past actions, and the player is allowed to co-define the game system as a whole.
Example. A scientist is murdered after announcing to have discovered the definitive solution to carbon emissions. The player investigates the crime, and his decisions determine how the plot of the game unfolds, generating new challenges and developments.

3.3 Adaptivity

Adaptivity affordances promote player proactive (anticipatory) or responsive adaptation to emergent environmental conditions, requiring engagement with disruptions in system dynamics and unanticipated possibilities, and favouring learning processes in conditions of complexity (Davis & Sumara 2006). Adaptivity affordances stem from the possibilities, nature and effects of changes within the game system.
Changes require players to understand and adapt to possibly unexpected, uncontrollable, and unpredictable events (Miller & Page 2007), through investigating their properties, impacts, involved elements and possible origins, applying complexity-savvy thinking (Bloom 2010), and modifying worldviews through reflection (Beinhocker 2013). Changes also influence the nature of the problems underlying gameplay activities, impacting on players' objectives and the amount of game state information available to them. Rules regulating change define the extent to which unpredicted phenomena are perceived as new emergent organisations rather than haphazard randomness.

3.3.1 Non-player-planned game state changes

The game engenders game-progress-relevant changes transcending the scope of players' plans and intended objectives, forcing players to cope with unexpected perturbations. These changes can be:

- i. *System-triggered:* arising independent of players' actions and decisions.
- ii. *Player-triggered:* side effects of players' activities.

Depending on their scope (Sweetser 2008), changes can be classed as:

- i. *Elemental*: affecting the state of individual entities without altering their relationships.
- ii. *Systemic*: affecting both individual state and relationships among entities, thus generating the perception that entire portions of the game system change as wholes.

Based on the relationship between originating and resulting events (McDaniel & Driebe 2005; Miller & Page 2007), changes can be classed as:

- *i.* *Causal:* changes can be traced back to, and explained through originating events, and/or properties and relationships of the elements involved (e.g. through cause-effect rules).
- *ii.* *Emergent:* changes cannot be traced back uniquely to and/or entirely explained through the originating events and the elements involved.

Example. In a business management game, decisions of commercialising a specific device (object of the action) generates satisfaction amongst prospective users (player-triggered, elemental, causal change) and concern amongst the population (player-triggered, systemic, emergent change), because of unexpected rumours (system-triggered, systemic, causal change) suggesting that the device could be inappropriately used to commit crimes.

3.3.2 Event autonomy

The time, place and mode of occurrence of game-progress-relevant events can be, to some extent:

i. *Unpredictable*: cannot be fully anticipated by the player. Fully unpredictable events require reactive adaptation, since the game only provides information after their happening. Partially unpredictable events afford proactive adaptation, since the game provides some amount of pre-emptive information allowing players' anticipatory thinking and planning.

ii. *Uncontrollable*: cannot be fully controlled by players. Fully uncontrollable events force players to adapt reactively to their consequences. A lesser degree of uncontrollability may allow players to influence the occurrence of events, preemptively adapting to them and affecting subsequent reactive adaptation processes.

Example. In a disaster simulation game, a natural hazard will inevitably strike (predictable and uncontrollable event), and the player can influence the consequences by implementing security and safety measures through urban planning and development.

3.3.3 Gameplay time management

The player has some degree of control on the flow of play time (e.g. the duration of turns; suspension of play sessions; etc.), affecting possibilities to evaluate the state of the game system and act consequently.
Example. In a turn-based urban development game, at each turn players can freely plan actions and decide when to move to the next turn, triggering the execution of the planned actions and receiving outcome feedback (player-controlled time management). However, a match lasts 150 turns, regardless of player decisions (system-controlled time management).

3.3.4 Evolution of gameplay potential

The gameplay potential (i.e. set of operations and mechanics allowing the player actor to interact with the game system) can change throughout the game, generating new possibilities and requiring players to adapt their approaches.
Example. The player actor is an eco-monkey living in a village where successful completion of gameplay activities grants new possibilities for cooperation with other eco-monkeys, facilitating success in more advanced activities.

3.4 Sociality

Sociality affordances facilitate meaningful social interactions among players, and between players and artificial-intelligence-based game agents, driven by and/or related to game events. These interactions enhance player engagement in complexity, since they facilitate processes of mutual adaptation (Miller & Page 2007) and the emergence of learning in conditions of complexity (Davis & Sumara 2006).
Synergetic and competitive interactions require thinking strategies essential to cope with complexity (Bloom 2010). Synergetic interactions facilitate trans-level complex learning, integrating individual and collective processes (Davis & Sumara 2006). Competitive interactions require social skills to plan how to defeat antagonists and manage events generated by them, originating conflictual relationships that force players to continuously evolve adapting to each other (Miller & Page 2007). Rules of synergetic and competitive interaction, combined with unpredictability, disruption and randomness generated by human behaviours, may function as enabling constraints, further facilitating complex learning and eliciting adaptive skills (Davis & Sumara 2006).
Sociality affordances stem from the types of social interactions required or permitted by game aims and rules, and the related supporting in-game technologies. They are also generated by out-of-game infrastructures supporting communication within the player community even when players are not playing.

3.4.1 Multi-player engagement

The game allows multiple players to play simultaneously. The number of participating players directly determines the complexity of game-related social interactions. Normally, the higher the number the higher the

complexity. In some cases constraints can limit the number of players simultaneously participating in specific game activities and/or present in a specific area of the game world.
Examples. Up to 50 players can engage at the same time in a game based on an environmental crisis, but only up to six players are allowed to collaborate in a mission.

3.4.2 In-game player synergies

Players are allowed and/or required to work jointly within the game world, in order to progress in the game. Players' synergies can be:

i. *Optional*: joint work facilitates the completion of activities, but is not required.
ii. *Mandatory*: the completion of gameplay activities requires simultaneous engagement of multiple players to cope with interdependent tasks.

Player synergies can be classed as (Zagal, Jochen & Hai 2006):

i. *Cooperation*, when players engage in joint action but pursue different objectives and payoffs.
ii. *Collaboration*, when players organise in teams and engage in joint action to achieve a shared goal, maximising the team's utility and sharing rewards and/or penalties.

Synergetic player connections can be:

i. *Player-defined*: players are allowed to choose when/how/with whom to work jointly.
ii. *Game-defined*: game rules define and fix the mechanics of interactions among groups and among players within the same group.

Mandatory, collaborative and player-defined synergies maximise player exposure to traits of complexity.
Example. In a setting based on a global oil crisis, players worldwide strive to improve the situation of their regions, providing advice to each other based on the outcomes of their local experiences (player-defined, cooperative synergy).

3.4.3 Competitive interactions

In order to succeed, players are allowed and/or required to compete with each other. Competition can be:

i. *Optional*: competing facilitates progress, but is not indispensable.
ii. *Mandatory*: defeating opponents is required to progress.
iii. *Direct*: players can interfere with each other directly.
iv. *Indirect*: players cannot interfere with each other directly.

Example. Players progress in a race through answering correctly to sustainability-related questions, without the possibility of interfering with each other (mandatory, indirect competition).

3.4.4 In-game communication infrastructures

The game provides infrastructures to facilitate in-game synchronous and/or asynchronous communication between players. Synchronous communication requires real-time presence and interaction of communicating parties. Asynchronous communication allows senders to post messages available at any time to large numbers of receivers. Synchronous approaches promote dynamic interactions generating a sense of 'live' community, while asynchronous approaches permit communication across larger timespans, allowing deeper thinking processes and facilitating the sharing of richer contents (Hrastinski 2008).
Example. Amidst a global oil crisis, players worldwide use a global internet portal to post reports and recommendations useful to better administer oil reserves (asynchronous communication infrastructure).

3.4.5 Out-of-game community spaces

The game has out-of-game facilities to foster communication even when players are not playing, facilitating the development of game-based communities.
Interactions in a game community may or may not be purposeful to game progress. Promoting game-progress-oriented interactions fosters the cooperative construction of knowledge, involving players in collective processes to discover and discuss how to tackle gameplay activities and contexts defining the game world (Steinkuehler 2008).
Example. Each player is in charge of the sustainable development of a city, and players can use the game web-site facilities to share their status, visit other players' cities and ranked them.

4. Conclusions

Sustainability learning requires the acquisition of domain-specific knowledge and the development of mindsets fit to foster sustainable action engaging in complex system dynamics. Facilitating sustainability learning requires bespoke, theoretically sound and operationally relevant models and practical tools (Tilbury & Wortman 2004;

Dieleman & Huising 2006). Digital games have remarkable potentialities to foster sustainability learning, although there is evidence suggesting that they are not always fully leveraged (Fabricatore & López 2012). To address this, we formulated a model to support the identification and analysis of game-based sustainability learning affordances, intended as game aspects facilitating player engagement in complex dynamics, sustainability-related problems and contexts, and/or conditions facilitating adaptive learning.

To confer theoretical soundness to our model, we integrated perspectives from complexity science, sustainability, education, learning and game studies to define criteria that game aspects should fulfil to function as sustainability learning affordances. To bestow operational relevance to our model, we extrapolated categories of affordances that can be found in games of different types, studying contextualised gameplay activities through a process that can be replicated to examine other products. Our model can be applied to support the selection of existing games for educational purposes, or to facilitate the planning and introduction of game-based learning affordances when designing new games. To further develop our research, we will examine a broader sample of games in order to iteratively test and refine our model, enhancing its generality through the theoretical saturation of the categories of affordances identified so far (Strauss & Corbin 2008). Furthermore, we plan to use the model to construct analytical instruments to assess the potential that games can offer to facilitate sustainability learning, based on the analysis of the affordances that they present.

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