Chapter X: Gaming on Environmental Issues

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Abstract

Contrary to popular belief, games are not only used to entertain. In fact, gaming has a long and rich history of being used for serious purposes, including being used on environmental issues. In this contribution, we will provide an overview of the use of gaming on environmental issues by discussing the history of the domain, what it means to use gaming as a methodology, and by illustrating its application in a number of cases. Games are useful in order to: 1) foster engagement and promoting learning in situations where environmental issues interface with humans (gaming as intervention tool); and 2) extract qualitative and quantitative data about system behavior and/or about behavior/responses of humans that are part of systems (gaming as research method). In discussing evaluation methods, a particular emphasis is placed in this contribution on state-of-the-art methods and techniques using game data, such as behavioral telemetry analysis and data mining, due to their promise for maturing the field. It will also become clear that games can be used as a method for a wide variety of purposes: for awareness, training, persuasion, participation, assessment, data collection, scenario analysis, and data analysis. We will end this chapter with a set of trends and challenges accompanied with advice for readers who are interested in using gaming on environmental issues.

X.1 Introduction

Digital gaming has become ubiquitous in our society over the past decades. People play games anytime and anywhere, across a multitude of hardware platforms from computers to mobile phones and tablets. Although it is difficult to pin down specific numbers on the size of the game industry, due to confidentiality associated with sales numbers, several reports (e.g., Newzoo, 2013) have highlighted the magnitude of the game industry, its rapid growth over the past decade and the increasing degree to which games are embedded in daily lives of any demographic globally. Current estimates suggest two billion people worldwide play digital games. The global game industry has grown 8-11% per year during the past decade, and by 2013 generated around $93 billion US dollars in revenue worldwide, pushing upward of a predicted , reaching $100 Billion plus in 2014 (Entertainment Software Association, 2014; Gartner Group, 2013; Newzoo, 2013).

In terms of who plays games, the old idea of the male teenager sitting in his room has long since been rejected: Data from the US Entertainment Software Association (2014) suggests that 57% of Americans play digital games, with an average age of 30-37 years depending on the source. Total consumer spending in the US games industry on games alone is over twenty billion USD, with Europe forming a market of similar size. The Asian market is bigger than either of the two former.

Furthermore, the gender balance is close to equal, and all age categories are represented among gamers. The recent rapid expansion in the games market has occurred alongside the expansion in the mobile technologies market, notably mobile phones and tablets. This is exemplified by PocketGamer.biz (2012) who reported 222,000 active games in 2012 on the AppStore alone. In summary, these trends signal that games have matured as a medium for *entertainment*.

In parallel with the rapid growth in the interactive entertainment market, games and gaming have experienced an equally rapid renaissance as vehicles for education, training, research or to generate awareness about a particular topic (Harteveld, 2011). Take for example the game *Foldit*, which fundamentally crowd-sources the task of folding proteins, in the process amassing 500,000 players and reaching several new discoveries in the process (Cooper et al., 2010). Or *World Without Oil* (McGonigal, 2011), which asks players to imagine what would happen in a world where they have to survive without fossil fuels. In truth, games have a long and rich history of being used outside the entertainment sphere.

An illustrative example is *Chess*. Nowadays this game is mainly perceived as more than entertainment in the context of professional competitions, yet in the past it was used to teach about warfare.

Unlike games for entertainment, the use of games for non-entertainment purposes, commonly referred to as 'serious games' (Abt, 1970), has by no means pervaded our society. Despite the long and rich history, the use of games for research or education is still generally considered an innovation and has so far not succeeded in fundamentally changing the way education and training operates worldwide, despite the development of literally thousands of these games. That being said, there are numerous successful companies developing educational games and they are slowly making their way into education at all levels. This includes when gaming is being harnessed for studying or teaching about environmental issues. In fact, the use of games has formed part of environmental studies as a field of research and domain of inquiry since its beginning.

An example of the long history and the advances going forward is Fredric Vester's (2007) *Ecopolicy*. In this strategy game players are in charge of a country (industrial, developing, or threshold). They have to consider politics, production, environmental stress, quality of life, education and other interlinked aspects of human life. Each decision results in a chain of effects and repercussions. These decisions and consequences are based on Prof. Vester's Sensitivity Model, a computerized planning- and management tool for complex systems. The educational objective is to gain insight into the complex character of our complex, interconnected world. The game started in 1976 as annex to an UNESCO study on urban systems in crisis, was followed by an award winning board game and then in 1985 by the first DOS-version as computer game. From 2008 to 2012 a modern *Ecopolicy* version was the center of a countrywide contest in Germany where more than 200.000 students took part.

In this chapter, the historical relationship between games and environmental studies or work will be described in more detail and with more examples, and the wide variety of uses of games in this context will be outlined. We illustrate that two main uses exist, namely: 1) fostering engagement and promoting learning in situations where environmental issues interface with humans (gaming as intervention tool); and 2) extracting qualitative and quantitative data about system behavior and/or about behavior/responses of humans that are part of systems (gaming as research method). A particular emphasis is placed in this contribution on state-of-the-art evaluation methods using game data, such as behavioral telemetry analysis and data mining. In our opinion, these advanced evaluation methods, referred to as 'game analytics' (Seif El-Nasr, Drachen, & Canossa, 2013), could literally be a 'game changer' for transforming gaming from innovation to a regular practice among practitioners and researchers – in environmental studies and beyond.

In the remainder of this chapter, we first provide a very brief overview of the history of games used in connection with environmental studies. We then discuss what it means to use gaming as methodology. Subsequently, we provide a number of compelling examples on environmental issues, to ground the previous material and for inspiration. From these informative overviews, we turn to describing how to accomplish gaming on environmental issues, first by explaining the design process and then detailing evaluation methods with a focus on game analytics. We end this chapter by discussing the challenges for using gaming and by providing a set of general guidelines for those interested in pursuing gaming for environment studies or issues. It is important to note that it is not possible to provide a complete overview of this entire domain of interest. Rather, the chapter serves as an entry point for the readers towards helping to navigate this fascinating landscape – and hopefully ensuring that no wheel is reinvented.

X.1 A brief history of games in environmental studies

Starting on a personal note, the first author's first experience with serious games was while he attended primary school in the Netherlands. There he was required to play a game called *Thuis In Het Milieu* (freely translated as 'At Home In The Environment'). In this digital game, released in 1990 and reminiscent of the popular entertainment game *The Sims* that was released exactly a decade later, players have to perform tasks in and around the house. All these tasks involve the environment. Amongst others, players have to control the radiators, clean the house, throw out the trash, take a shower, and do the laundry. How these activities are performed affect the environment, and players receive at the end of the week an 'Environmental Bill' that summarizes in detail how well players conserved energy and thereby reduced the environmental footprint of the household. The game was sponsored by the Dutch Foundation for Environmental Education and dealt directly with environmental issues.

For the second author, who has a background in the geosciences, the first experience with serious games was during college, back in the 1990s when climate research started gaining serious momentum. At the time, several universities in Europe participated in simulation challenges that aimed at educating students about the usefulness of large-scale datasets and global climate models. This helped spark interest among the students in adopting more computer-driven approaches in their work.

Games following similar footsteps, i.e. fundamentally trying to inform and educate about environmental issues, are today common and developed by a range of agencies, organizations and companies worldwide. Indeed, it would seem that every large government agency or organization with an educational web portal or –function, employs games one way or another. Recent examples that illustrate the wide range of institutes that promote the use of gaming include:

- *Hurricane Strike!*: A game targeted at middle school students that tasks them with preparing for a hurricane strike in their house. It is maintained on the MetED website, which provides education and training resources to benefit the operational forecaster community, and was developed with funding by the US Federal Emergency Management Agency (FEMA) and the National Weather Service (NWS).
- *Gizmos*: A library of hundreds of interactive online simulations across the sciences and math for pre-college students, including on clouds, humidity and the greenhouse effect. They have been developed by ExploreLearning, a company that develops online solutions to improve student learning in math and science.
- *Y Science Laboratories*: A set of realistic and sophisticated simulations for chemistry, biology, physics, and the earth sciences. They were created at Brigham Young University and are disseminated through Pearson Education to middle school students and up.

Much later, while in college in the early 2000s, the first author experienced the analog game called *Harvest* (the digital version is known as *Fishbanks*). In this game, players represent various independent fishing companies that have to decide each round how many fish they harvest from the ocean. Although players do not know how many fish are in the ocean, they do know the rules of the eco-system. After each round, the fish population will be doubled, representing spawning of new fish stock, up to a specific maximum threshold representing the ocean's capacity to support a certain amount of fish. The goal for each player is to maximize profits by harvesting as many fish as possible. The game stops after ten rounds or when there are no more fish in the ocean. The latter is more likely to happen as this game represents the 'tragedy of the commons'. The various players will act according to their self-interest and forget about the whole group's long-term best interest by depleting a common pool resource. To prevent this from happening, oversight and/or incentives may be needed. Players can experiment with such interventions. For example, players may coordinate and ask that each fishing company is transparent in how many fish they harvest. However, even with such 'policy interventions', cooperation may not happen, as players may say one thing and do another.

This simple game lets players experience a critical issue in environmental studies, and even allows for the exploration of solutions. It was developed in the 1980s by Dennis Meadows. He is the co-author of *The Limits to Growth* (D. H. Meadows, Meadows, Randers, & Behrens, 1972), a book on the use of computer modeling of exponential economic and population growth with finite resource supplies. This book has had a significant impact on the conception of environmental issues and therefore on the establishment of the field of environmental studies (Victor, 2008). Meadows firmly believed in using gaming as a vehicle for teaching about environmental issues. He designed many other games, some of which are documented in his *Systems Thinking Playbook* (Sweeney & Meadows, 2010).

In 1997, Ulrich (1997) wrote a review about gaming on environmental issues. According to him, gaming as a method is well suited for dealing with complex interrelated problems as characterized by (Sterman, 1994) and therefore has significant potential in the application to environmental problems and sustainable development. Focusing specifically on games with 'social interaction' between players and the literature, he found thirty-one games with differing characteristics and underlying models. The earliest games on environmental issues reported are *The Commons Game* by Richard Powers (1992) in 1975, a nowadays considered classic game that like *Harvest* explores the tragedy of the commons and that has been re-released as *The New Commons Game* in 1992, and *METRO-APEX*, a game developed by Richard Duke in 1975 as well. Duke is one of the founding and honorary members of the International Simulation And Gaming Association (ISAGA), a community of professionals that met in 2014 for the 45th time at their yearly conference and celebrated the re-release of Duke's (1974) classic book *Gaming the Future's Language*. In the review it became further clear that the majority of the games were geared towards 'understanding mechanisms' within the system of interest, were applied in a University setting, and focused on environmental issues of global concern.

From the 1990s towards the early 2000s, the development of serious games on environmental issues quietly escalated, but without widespread adoption in the educational system or for research purposes specifically. However, a decade after Ulrich's review (1997) a special issue of the Journal of Simulation & Gaming was dedicated to a specific topic within environmental studies: natural resource management (NRM). Guest editors Barreteau, Le Page, and Perez (2007) argued there that traditional NRM approaches based on centralized optimal allocation of resources between potential users have failed because of the complex and adaptive nature of socio-ecological systems. They suggested a participatory approach, one that considers users within the allocation process and where collective learning takes place. As a method, gaming might be an effective participatory approach: *'It is expected that by taking part in the simulation experience from within, participants will enhance their understanding of the underlying model and improve their knowledge through collective interaction'* (p. 186). They continue by emphasizing that gaming is useful for education, opening up new perspectives, and facilitating collective decision-making processes. It is the latter where gaming will be the most powerful for NRM, as in most cases natural resources face multiple, interacting users who will need to coordinate their efforts to avoid overexploitation (see the *Harvest* game).

An example of collective decision-making and learning on natural resources is the *PowerPlay* game by Ruth et al. (2006), which focused on energy efficiency improvements in the residential and commercial sectors. The game is run interactively by decision makers, and allows them to explore various future scenarios and the interaction between the decisions made with regards to e.g. utilities, households and firms. The focus of *PowerPlay* was to function as a vehicle for decision makers to gain an understanding of investment strategies and consumer choices.

More recently, in 2013, another special symposium issue was published in the Journal of Simulation & Gaming, this time on the specific topic of climate change and with a foreword by Dennis Meadows. The guest editors Eisenack and Reckien (2013) describe how gaming has *'a long history as an alternative to traditional instruments for awareness raising, education, training, and research for environmental issues'* (p. 246) and that 'Climate change has now (sadly) become a *subject* in its own right' (p. 247) for which gaming can and have been used. Specifically, based on their observation that very limited progress is made with negotiations at the UN level on *'one of the greatest challenges of our time'*, they see gaming as an alternative approach to represent, to research, and to teach issues of global environmental change, and one that:

> *…can be particularly useful to analyze and teach alternative and complementary views on climate change. Games can simulate quite complex actor relations, between nation-states and between transnational, subnational, individual, and hybrid actors. They can focus on individual behavior, but they can also teach political affairs. Games can offer new ways to raise awareness and empower people to deal with climate change* (Eisenack & Reckien, 2013, p. 246).

The first contribution in this issue gives a systematic overview of existing climate-change games until 2011 (Reckien & Eisenack, 2013). The authors conclude that (as also noted above) these types of games are so numerous today that in gaming too, climate change should be seen as a subfield on sustainability and environmental issues in its own right. They found about eight-dozen published games, dating back as early as 1983 but with the majority being developed in the most recent years, and selected fifty-two more sophisticated games for further analysis. This is an indication that the use of gaming is increasing for addressing the environmental issue of climate change. This use may be fostered by initiatives such as Al Gore's Climate Reality Project, which encourages the design and development of games (Carr-Harris, 2011).

Most recently, in 2014, Katsaliaki and Mustafee published a review with a focus on sustainable development. According to the authors, a profound solution is needed for the adoption of sustainable development practices and one way of increasing awareness towards a more sustainable future is through serious games. In this review forty-nine games were evaluated, of which the majority (61%) was launched between 2008 and 2010. Surprisingly, none of these overlap with the review by Ulrich (1997) and much in contrast to his review the authors concluded that these games are targeted at youngsters (and not University students), are played individually, and are accessible online. The latter characteristic is a sign of technological advancement from 1997 to 2014, but everything else highlights either a change of interest in the use of gaming and/or the fragmentation of gaming on environmental issues.

This brief history shows that much has happened already with gaming on environmental issues and these sources do not even capture the complete picture. For example, a 2012 report called *Games for a New Climate* states that:

> *…to date, the Red Cross/Red Crescent Climate Centre and partners have co-designed over 25 participatory games, and delivered more than 150 game-based sessions in more than 30 countries in five continents. With just some beans, dice or other simple objects, these games convey the complexity of decisions given new climate conditions, reaching over 3,000 participants ranging from subsistence farmers, to development and humanitarian workers, to donors, academics, businessmen and elected officials* (Mendler de Suarez et al., 2012, p. 1).

None of the twenty-five games developed by Red Cross/Red Crescent Climate Centre are listed among the eight-dozen games that have been considered in the review by Reckien and Eisenack (2013). This may be an indication that this review is lacking a great many more games.. Such an omission is by no means an indication of poor scholarship. In our view, this again confirms the fragmentation in gaming and environmental studies, as well as the related issue of dissemination. The fields of gaming as well as environmental studies are interdisciplinary, practiced by people from a variety of disciplines and in various contexts, from academia to industry. As a result, outlets for dissemination vary too. In terms of just journal publications, we can find them in domain-specific outlets (e.g., Ocean & Coastal Management), educational (e.g., Computers & Education), or those devoted to games (e.g., Simulation & Gaming). This fragmentation makes it inherently difficult to obtain a thorough overview of the state-of-the-art of the use of games in associated with environmental studies.

Even in the types of games an enormous diversity exists. The Red Cross/Red Crescent Climate Centre games use simple game elements to create an experience with multiple players and operate in the physical world, whereas a game like *EnerCities*, in which players are challenged to develop an eco-friendly city, are fully digital and played online individually (Knol & De Vries, 2011). Due to new technologies, it goes nowadays further than these design dichotomies between analog versus digital and single-player versus multi-player. A game such as *Environmental Detectives* (Klopfer & Squire, 2008) is played in the physical world, augmented by a mobile device (referred to as an augmented reality game in the games literature). In this game, players play the role of environmental engineers who have to locate the source of a toxin spill, identify who is responsible for it, design a remediation plan, and brief stakeholders on any health and legal risks – and this all within two hours. In addition to these mobile games that augment reality, a genre exists that radically changes how we look at our reality entirely: Alternate Reality Games (ARGs). One relevant example concerns the aforementioned *World Without Oil* (McGonigal, 2011). Almost two thousand players imagined that an oil shock had happened and they had to imagine and document their lives under the conditions of not being able to use oil at all. The idea behind this effort is that through this exercise we can foresee what the future might bring and get prepared when an environmental issue actually happens. This logic is practically similar to the many games oriented at risks and disasters. The crucial difference is that players do not enact their imagination in a virtual environment; they do it in their real world.

In summary, the brief history presented here is by no means exhaustive. It does not even constitute the phrase 'a brief history of nearly everything' on gaming on environmental issues. However, it does provide a 'quick and dirty' overview of what has happened on this topic. The main take-away is that much work has been done, more than the current authors are aware of, and an opportunity exists to 'stand on the shoulders of giants' to use the phrase denoted by Isaac Newton – or at least learn from past experience and failures (notably concerning games that are simply not being used by anyone) with using games in connection with the environmental sciences. Also, this brief history provides the necessary context against the rest of the chapter, which focuses on presenting games and gaming as a methodology for environmental studies.

X.2 Games as methodology

With such an incredible diversity amongst games, whether for entertainment- or serious purposes, it is hard, if not impossible to capture a single definition or perspective on what games are. In addition, over time, as new technologies and game genres appear, we are forced to reconsider our views on games and gaming. For example, for a long time it has been argued that gaming happens in a space separate from reality. With the arrival of Alternative Reality Games (ARGs), which rely on the integration of gaming into the physical reality, this notion has been challenged (Montola, 2005). In our view, given the basic propensity of humans to play, and learn by playing, this malleable nature is the medium's strength. As of today, serious games have been used for almost any imaginable topic in any possible domain (Harteveld, 2011). The use of gaming in a domain such as public policy (Mayer, 2009) meets different needs and requirements than in health (Kato, 2010), and this results in different kinds of games and views on what gaming is. For one it might be a tool for dialogue and process management and for another it is an intervention to accomplish behavioral change.

However, agreement seems to exist on a number of characteristics that games have across all types of usage as well as a number of qualities that make gaming appealing as methodology for creating an impact. In this section, we will first elaborate on what we could tentatively refer to as the agreed upon *characteristics* of games, before we move on to discussing the *affordances* of gaming beyond entertainment. We end by describing the wide variety of *possible uses* for which gaming has been used, with the idea of inspiring scholars and practitioners in the field of environmental studies how these uses can be translated to their needs. Table 1 summarizes the insights of this section – what the characteristics, affordances, and possible uses are of games.

Table 1. A summary of games as methodology: its characteristics, affordances, and possible uses.

		Possible uses	
Characteristics	**Affordances**	**Intervention tool**	**Research method**
Participatory activity: It involves an experience with one or more participants called players.	**Pervasive:** People play on anything, anytime, anywhere, and anyhow.	**Awareness:** It provides knowledge or perception of a situation or fact.	**Assessment:** It can judge individuals, groups, structures, processes, and tools.
Agency: It needs to allow for meaningful actions and provide perceivable feedback.	**Models and simulations:** It can represent (complex) aspects of the physical world.	**Training:** It gives the opportunity to practice a particular skill or enforce a type of behavior.	**Data collection:** It can elicit and extract desired output from people.
Alternate reality: It is imagined and	**Engaging:** It has the ability to captivate	**Persuasion:** It can influence a person's	**Scenario analysis:** It allows performing

fictional but still based *on* and *in* reality.	and sustain the attention.	beliefs, motivations, and behavior.	what-if scenarios on the future or past.
Structured: It is organized by means of explicit rules and clear goals.	**Positive impact:** It has a variety of proven benefits.	**Participation:** It engages people to take part in an endeavor and make their voices heard.	**Data analysis:** It allows for exploratory and confirmatory scientific approaches to study phenomena.
	Data exhaust: It can track and monitor every possible action.		

X.2.1 Gaming untangled

Our efforts for providing a better understanding of games are by no means as complete and exhaustive as elsewhere, and readers are encouraged to consult those works if they want to find out more (Caillois, 1958; Juul, 2005; Salen & Zimmerman, 2004). We further realize that the following four characteristics do not apply necessarily to all types of games; however, these descriptions will help generate needed understanding of gaming as methodology. To start with, gaming is a *participatory activity* with one or more active participants referred to as *players*. This key characteristic of involving players is what sets gaming apart from the use of computer models and simulations, where social entities such as people are represented as autonomous agents based on mathematical and stochastic models.

For a game to be a game, mere involvement is not sufficient; player effort is needed. Players have to actively exert influence on what happens in a game by making decisions. This characteristic is better known as *agency*. Murray (1997) defined this as 'the satisfying power to take meaningful action and see the results of our decisions and choices' (p. 126). Player actions are meaningful when player intentions are met with perceivable consequences, that is, when what the player desires within the affordances provided by the game environment is answered with a clear reaction after the player takes the action (see also Harteveld & Sutherland, 2014). Two concepts play a crucial role in establishing agency. First, a game needs to be able to allow for player influence. This is the *openness* concept (D. L. Meadows, 2001). Compared to a traditional simulation model, a game has to 'open up' and provide for opportunities where players can make decisions. Second, *feedback* is essential. A game needs to be able to respond to player decisions and this necessitates the inclusion of a feedback system.

Players take actions in what we consider an *alternate reality* (Warmelink, 2014). The adjective 'alternate' denotes that the activity is imagined and different from what we know as the physical world. This is what allows us to game the future (Duke, 1974) or the past (Champion, 2010), and what allows us to engage in the various fantastical settings we know of entertainment games, among others. In addition, this characteristic is what makes us able to safely experiment with different 'what-if' scenarios and learn how to do better through trial-and-error. The noun 'reality' denotes that the activity is based *on* and *in* reality. First, it is based *on* reality because how fictional a game might be, it is still based on our understanding of reality or of constructs developed as part of human culture. Every game, even *Super Mario*, has a model of reality. For example, this particular game does include the concept of gravity. We also know what plumbers and mushrooms are from our own physical world. Second, it is based *in* reality because players step into the activity with their personality, previous experiences, and expectations. They also step out of the activity with impressions, skills, and other 'gains' that may prolong beyond the activity. If the latter were not true, serious games could never make an impact. The entire idea is that these games are intentionally designed and used to accomplish 'something' in reality.

Last but not least, gaming is a *structured* activity. It is organized by means of explicit *rules* and clear *goals*. Rules provide constraints and affordances on what players can do; goals give players an intent. Naturally following the presence of goals in a game, player effort is required to reach those goals. To accomplish this need for putting players to work, a game provides conflicts, challenges, and/or obstacles that need to be overcome. Creating this structure is one of the hardest tasks in game design. It requires building a consistent and coherent alternate reality where every player action leads to a sensible, perceivable consequence (Harteveld, 2011).

We have been using the terms ‘game’ and ‘gaming’ somewhat interchangeably so far and the difference in meaning is relevant. The term game refers to an *artifact*. As an artifact, a game is designed to enable an activity we refer to as ‘gaming’. Salen (2007, p. 9) seems to agree with this view and elaborates as follows:

> *Gaming constitutes the sum total of activities, literacies, knowledge, and practices activated in and around any instance of a game. Gaming is play across media, time, social spaces, and networks of meaning; it includes engagement with digital FAQs, paper game guides, parents and siblings, the history of games, other players, as well as the games themselves.*

In other words, speaking of games makes us overemphasize the importance of the artifact at the expense of the context in which the artifact is used and what emerges from engaging with the artifact. It gives the idea that the experience is entirely mediated through the artifact, whereas various contextual factors such as facilitators and fellow players, to name but a few, have a major influence on the resulting experience. In addition, the context also gives opportunities for increasing the impact. For example, providing additional material may strengthen what players learn from a game. For this reason, we believe that creating a successful experience necessitates to look beyond the artifact alone. A game designer is designing an activity and the game is within this process a means to an end. This difference in meaning explains our preference for speaking about gaming next to games.

In summary, as for gaming, the aforementioned should have clarified that it is a structured, participatory activity with one or more participants called players who have agency in an alternate reality.

X.2.2 Motivating serious games

In the history section above, we outlined the use of serious games and their long and rich history. The appeal for this use differs depending on the specific application domain and the overall goal of the serious game in question. Several scholars have motivated the use for education (Gee, 2007), public policy (Duke & Geurts, 2004), and persuasion (Bogost, 2007), to name but a few applications. Steinkuehler (2013) led a White House Academic Consortium on Games for Impact and this consortium concluded that five affordances exist that make gaming a powerful tool:

1) First, games are *pervasive*. Especially in the 21st century people play on anything, anytime, anywhere, and anyhow. Games have become a dominant medium of how we consume information and learn. This means an infrastructure exists, more so than ever before, that can be harnessed for reaching people to have them participate in research and/or educate them.
2) Second, games include *models and simulations*. This is another way of saying that games are based *on* reality. The game *Civilization* illustrates this well (Squire, 2011). In this game, players have to build up a civilization starting in 4000 BC and develop this through the ages until modern and near-future times. The game models the development of civilizations over pretty much the entire course of human history. As Squire notes, the game has a geographic-materialist simulation of history, which is a particular version of history, one not far from Jared Diamond's (1997) Pulitzer Prize winning *Guns, Germs, and Steel*. The game shows how geographical conditions affect population growth and availability of resources, among others. By playing with this simulation model, players will learn about world history in a different manner. In certain circumstances games are even built around an existing model or simulation, such as with the aforementioned *Ecopolicy* game, which is based on a cybernetic model called the Sensitivity Model (Vester, 2007).
3) Third, games are *engaging*. They have the ability to captivate and sustain the attention of players, even for otherwise tedious tasks. An example of the latter is the *ESP Game* (Von Ahn & Dabbish, 2004). Search engines allow us to search for pictures. The accuracy of search requests is dependent on the tags that are associated with pictures because computers have a hard time

recognizing pictures. Humans are, however, very good at this. To improve search requests, a game was developed where players have to tag pictures, thereby creating for a more elaborate and accurate database that search engines can use to respond to search requests. The designers accomplished to make this tedious task into a fun activity by having players collaborate with an unknown player. Both players tag independently from each other a picture and the goal is to find agreement on a tag as fast as possible. The faster an agreement is independently made, the more points both players will gain.

Engagement is not just a matter of having people do what they otherwise would not. It is much more about having them deeply involved in an activity. From an educational perspective, research has pointed out the benefits of active and experiential learning – from the educational philosopher John Dewey all the way up to today's visionaries in games such as James Paul Gee. The argument is basically that the engagement affordance fosters deep learning of content (Shaffer, 2006). From a research perspective, one can argue that people's responses in a game setting, albeit artificial, is still more natural compared to responding to a questionnaire or their behavior in a lab setting. Of course, observing people in the physical world provides for much more valuable data, but this is inefficient, not always possible, and cannot be controlled for (Harteveld & Sutherland, 2014). Gaming provides for a methodology that bridges the sterile and inauthentic lab experiments with the difficulty of performing natural experiments.

4) Fourth, games have proven to make a *positive impact* on cognition and behavior. Although more evidence is warranted, various studies have found conclusive evidence on the benefits of playing games (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Granic, Lobel, & Engels, 2014; Young et al., 2012). Therefore, we can be assured that gaming is based *in* reality and has the affordance to make a difference. Some proof will, however, be hard to gather. For example, gathering unquestionable evidence that a game changed an organizational culture or created for a resilient response to a real disruption seems very unlikely. In those circumstances, proxies will

have to be defined that will provide for enough confidence that gaming is a valuable approach.

5) Fifth, (digital) games enable a *data exhaust* as each and every possible action can be automatically tracked and monitored in a controlled environment. This potential for large data has led to the emerging field called *game analytics* (Seif El-Nasr et al., 2013), which is broadly defined as the application of business intelligence-based theory and methods in the specific context of games. Of notable interest here is the possibility of tracking player behavior and the response of the game system. This is referred to as behavioral telemetry. It also led to the recent interest in using games for assessment (Shaffer & Gee, 2012). One of the recent funded projects using game-embedded formative assessment is *SimCityEDU: Pollution Challenge* (GlassLab, 2014). This adapted educational version of the *SimCity* franchise with a focus on environmental impact, which the developers describe as a 'game-based learning and assessment tool for middle school students', provides tools to formatively assess students' problem-solving abilities, explanations of relationships in complex systems, and abilities to read informational texts and diagrams. Although in principle user behaviors can also be tracked for physical games or cross-media games, the collection process is more resource demanding and is thus generally not performed to anywhere near the level of detail possible using behavioral telemetry tracking.

Various reasons exist why games are and should be used beyond entertainment. We discussed here five affordances, as provided by the White House Academic Consortium on Games for Impact. Games are pervasive, provide for engagement, include models and simulations, create for a positive impact, and deliver a data exhaust.

X.2.3 Applying games for serious purposes

In the above we have explained what gaming is and why it is applied for serious purposes. Here we detail how gaming is used for creating an impact in relation to the environmental sciences (see also Harteveld, 2011), and give a few examples for inspiration. An overall distinction is whether the application is targeted at *players* or whether it is geared towards an *object* of interest (Harteveld & Sutherland, 2014).

If gaming is used for the player, it might be for awareness, training, persuasion, or participation (see Table 1). An example of persuasion is *The Chiquita Banana Game*. The company Chiquita received a Rainforest Alliance Certificate for growing their bananas with respect for their employees and environment, and yet many people may believe that this is another global company that takes advantage of their dominance. To make people understand that Chiquita runs their company (or at least the actual banana growing component thereof) in a sustainable manner, a game was created in which players have to run their own plantation and grow bananas. By playing this game, players should gain an idea of how bananas are cultivated by Chiquita and may favorably adjust their opinion about the company as a result. Whether the game has been successful at accomplishing attitude change is an open question, but it is indicative of how games are increasingly used for shaping brand perceptions.

An example of participation is *Community PlanIt* (Gordon, 2013). This digital playful environment seeks to lower the barriers for civic participation and increase community engagement. Civic leaders and town planners can use this environment if they seek community input for trying to imagine solutions to complex issues. In the game, players have to complete challenge questions and themed missions to earn 'coins' that they can pledge to help win money for local causes while contributing to a real world planning process. The game has been successfully implemented in various planning processes, one of them being in Detroit for the Detroit Master Planning, a 50-year planning of the future of Detroit. Over a thousand players participated, producing over eightthousand comments, and accomplishing a vision that got integrated into the final master plan.

Most uses of games for serious purposes are targeted at the players and can be broadly defined as educational. Even a game such as *The Chiquita Banana Game* can be qualified as such. Persuasion involves 'teaching' a person what to think and do. Fishbein and Ajzen (1975, p. 11) defined attitude also as a person's 'learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object'. Learning plays a critical role across uses as awareness, training, and persuasion. Another significant part targeting players involves what *Community PlanIt* embodies: engaging people.

For some uses engaging people is a means to an end, but in others it is an end itself. In public policy and urban planning it is, for example, of crucial importance to get local support and a game may reach people in ways that other media may not. Therefore, we added ‘participation’ as a possible use. Together, we conceive of using gaming to target players and its uses for awareness, training, persuasion, and participation as *gaming as intervention tool*.

If gaming is geared towards an object of interest, its use depends on the underlying objective for looking at this object. It might be used for assessment, data collection, scenario analysis, or data analysis (see Table 1). An example of scenario analysis is *SimPort* (Bekebrede, 2010). This game was developed in collaboration with the Port of Rotterdam Authority in the Netherlands to explore the construction and exploitation of a future harbor extension. The game simulates 30 years of harbor development and exploitation and players have to collectively come up with a plan for how to establish a successful harbor extension. By gaming the future and comparing the outcomes of various sessions, ‘possible realities’ may become clear as well as influential factors and concerns, while of course keeping in mind the game’s limitations.

For data collection the various citizen science projects are relevant to mention (Franzoni & Sauermann, 2014). *Citizen science* refers to individuals who voluntarily participate in a scientific process, often constructed and framed by professional researchers, by contributing their time, effort, and/or resources without having necessarily a formal science background. Existing digital forms on a large scale involve using idle computing time, registering observations, or tapping into human computational power. Non-digital forms include many forms of environmental monitoring and volunteer programs. The aforementioned *ESP Game* is an example of the tapping into human cognitive power. It uses the human computational power of picture recognition to establish search algorithm accuracy.

An example of registering observations is *YardMap*, which is one of several citizen science projects at the Cornell Lab of Ornithology. The project is designed to cultivate a richer understanding of bird habitat by collecting data through asking individuals across the country to literally draw maps of their backyards, parks, farms, favorite birding locations, schools, and gardens. *YardMap* provides users landscape details through Google Earth and tools to draw and manage landscapes sustainably. Although it is not a game by any strict definition, *YardMap* is an illustration of how data can be collected in an alternative manner than the usual surveys. The idea of using gaming for these types of projects is that the success of citizen science stands or falls with the participation of people. Issues of engagement are of significance because the kinds of tasks that citizen scientists undertake are sometimes mundane or repetitive, or they may be complex, requiring specialized training or knowledge. In either case, it is of importance to keep the user involved and one of the affordances of games is precisely this, to engage.

Uses targeted at an object of interest may be about humans too. Gaming can shed light onto strategic behavior, decision-making, or human behavior in general. Here again we should not forget about the limitations of this methodology, yet through gaming we can arguably distill far more believable behavioral patterns than a survey, which suffers from a response bias and the need to give explicit responses, and provide for a more authentic experience than a laboratory setting would. If the interest concerns system behavior rather than individual or group behavior, the advantage that gaming provides is the inclusion of natural – not modeled – social elements as part of a system. It can be argued whether behavior in the game translates to behavior in the real world, and this question should be of concern to anyone engaged with gaming, but so can we argue too about the validity of autonomous models that represent social behavior. Whatever objects researchers and practitioners may have in mind, we consider using gaming to target an object of interest as *gaming as research method*.

What distinguishes gaming as intervention tool from gaming as research method is that with the first the players are empowered or influenced. From a perspective of empowerment, playing the game is an intervention with the aim of improving existing conditions for players. They may learn, give a voice and express their opinion, or behave in a manner that is personally beneficial, such as healthy eating habits and exercise. From a perspective of influence, playing the game may lead to improving conditions for others by changing people's view. Such influence may be performed by companies (think of *The Chiquita Banana Game*) or politicians, among others. With gaming as research method, on the other hand, players are a means to an end. The objective is to extract insights on a particular phenomenon, which requires using human input. This duality represents the two distinct branches of science: the design and analytical sciences (Klabbers, 2006). With the *design sciences* the basic idea is to build and assess artifacts; with the analytical sciences the aim is to develop and test theories. Both sciences apply different criteria of success, with the design sciences focused on making an impact in the world, and the analytical sciences using the scientific method to produce knowledge about the world.

Cross-fertilization between the two branches of science and hence the two main uses of gaming is possible. In fact, we argue that it is intrinsically part of serious gaming research. First, any such research involves the use of a game as artifact, which necessitates building and assessing a game. Even when using an existing game, that game still needs to be assessed for its utility of being used for studying an object of interest. Second, gaming per definition involves players, irrespective of the game and its intent. After playing a game, players will have obtained an experience and learned something, whether the game is intended as an intervention tool directly or not.. Such realization happened for example with *SimPort*:

> *The simulation game is, in the first place, meant for staff of the Port of Rotterdam. But its emphasis on strategizing, project management and teamwork make it appropriate for others as well, such as students and (young) professionals as part of their education or training courses…[It is] a versatile learning tool (TU Delft, Tygron, & Port of Rotterdam, n.d.).*

That said, the strength of the impact of gaming as intervention tool or the rigor of gaming as research method does depend on the priorities of its use. Due to this, researchers will need to make trade-offs in how they deploy their game. For example, providing immediate feedback to players may be desirable from a design scientist perspective, to have players learn and reflect on their actions, yet this will confound the results from an analytical scientist perspective, as the feedback itself will change the behavior of the players going forward.

X.3 Illustrating environmental issues and gaming

In the previous section we elaborated on games as methodology in general. In this section we consider how this can translate to gaming on environmental issues by examining a number of cases. We have chosen for this depth over the breadth of discussing the larger variety of gaming on environmental issues for two reasons. First, others have written fairly recent reviews on this topic (see history section above). Second, the provided detail will help to appreciate what gaming is and does in the context of this topic. In our examination, we pay attention to detailing the design and evaluation, which are the two topics that we elaborate on in the next sections. We chose three cases that each represent one of the core possible uses of. In this manner, we are representing the diversity that can be found in this area.

X.3.1 Awareness: EnerCities

EnerCities is an online, single-player game funded by the European Union to enable youngsters to grasp the complexity of an abstract topic such as sustainability and energy conservation and stimulate energy-conservation awareness, attitudes, and behaviors of youngsters in a fun way, inside and outside of classrooms (Knol & De Vries, 2011). The game is specifically targeted at secondary school students and is available in six languages. It is a sandbox simulation game (or free-roaming game) reminiscent of *SimCity*, i.e. a game with a virtual environment that players are free to explore, and where there is considerable freedom in choosing how and when to approach game goals. In the game, players start with a small village and a small piece of land. Players act as a ‘God’ and can build in a time period of 100 years, starting in 2010. They can implement different types of residential areas, industries, environmental objects, objects to boost citizen’s well-being, and renewable/non-renewable energy sources. In making these decisions, players have to consider the production of sufficient energy, revenue sources to enable future investments, and the limited availability of fossil fuels. The game’s main goal is to balance the well-being of people, the environment, and the economy while supplying the growing city with sufficient electricity, implementing energy conservation and CO2 emission measures, and minimizing fossil fuel use. The game uses ‘levels’ (akin to chapters in books) to structure the player progress. To progress from level to level, different sub-goals need to be completed, such as building 100 houses. If those sub-goals are reached, players will go to the next level, where newer targets are introduced and new implementation options become available. Player performance is expressed in an overall score and specific scores on well-being, the environment, and the economy.

The designers behind *EnerCities* chose to illustrate and reduce the complexity of environmental issues by simulating how it works in a clearly demarcated area of a city over a long-term time span. They also provided a framework of introducing game mechanics gradually, in order to avoid immediately overwhelming players with too many choices and rules. Providing additional choices along with player progression and giving the player sub-goals, helps lead the players in the right direction and assists with establishing a learning curve that is not too steep. Finally, players receive advice from a girl called Alex based on what happens in the game. All these design choices are geared towards keeping players engaged and making a difficult topic understandable to youngsters. The game is relatively short; it has four levels that will take altogether 15 to 45 minutes to complete depending on the player's strategy, ending up with the player having built a 'level 5 metropolis'. This design element is illustrative for a game used for awareness and what distinguishes it from the use of training that requires often many hours of engagement.

To evaluate the game, researchers performed a field experiment to determine whether playing the *EnerCities* encouraged learning about sustainability, renewable energy, and energy conservation. In addition, it was explored whether the game would positively influence player's stance towards energy saving in their daily lives. In this experimental design, over eight hundred students from five different countries initially participated, where about half played the game (experimental group) and the other half did not (control group). Both groups filled out a single questionnaire and from this questionnaire a significant difference was found in awareness and a motivation to learn more from those who played the game. Stronger attitudes towards saving energy at home were also found – for example, participants in the experimental group expressed to turn off the TV after use instead of using the standby function and taking shorter showers. Although these results do not confirm if the actual behavior changed, they do indicate that the game made an impact on player's awareness of environmental issues.

X.3.2 Training: Levee Patroller

Levee Patroller is a game where players can walk freely around a 3D environment – the purpose of the movement being to find all potential levee failures and appropriately deal with them using the tools of the game (e.g., handbook, map, etc.). Upon finding a failure, players have to recognize the failure, report its characteristics, assess the entire situation, and take actions if needed. Failures can change over time, requiring players to return to the problem locations to determine if the potential failure worsened. If players do not appropriately deal with failures, a flooding results (see Figure 2). Players communicate with a coordinator who provides tips, feedback, and directions. Throughout and at the end of an exercise, players also receive feedback on how they performed according to the learning objectives. One scenario takes about 45 minutes up to an hour to complete.

Levee Patroller was developed to train practitioners that have to deal with levee failures (Harteveld, 2011, 2012). Playing the game enables practitioners to make decisions in a safe environment and learn from their mistakes. More importantly, this game is an exemplar of allowing people to make sense of phenomena that are difficult to observe in the physical world. The game was designed in collaboration with various relevant stakeholders. It was a challenge to create a game that would please each stakeholder, as failures and procedures differ greatly among the stakeholders. To account for this, it includes flexibility in assigning failures and responsibilities through a scenario generator. The game was carefully tested and iterated with the end-users who have few computer skills and little to no game experience. One of the changes that resulted from this is to tell the players upfront how many failures they have to find. The small change of establishing such *clear goals* made a world of difference: from an experience where players asked if they could stop, it turned into an experience player's attention was sustained until all failures were found and players got frustrated for having to stop. Another critical design decision was to use the learning objectives as guidance. All the activities and resulting performance evaluation was driven by what the players ought to learn.

(a) Levee failure (b) Flooding

Figure X.1. Two screen shots of the game *Levee Patroller*

A quasi-experimental efficacy study proved that the game was effective: after three weeks of training with the game, participants starting with limited practical experience perform as well as experts. Moreover, learning transferred to real world situations: participants made sense out of real pictures on a test just as well as on virtual ones. Learning was also engaging: 80% of the participants played almost all exercises and spent over 10 hours on the game-based training and enjoyed doing this. Player scores strongly correlated with test performance in the end, thereby showing that this game may be used for assessment in addition to training. As for training, *Levee Patroller* illustrates the potential of gaming to prepare a professional workforce for a resilient and sustainable future.

X.3.3 Assessment: Marine Spatial Planning

An increased need exists for Marine Spatial Planning (MSP) due to how marine ecosystems are affected by human activities (Mayer, Zhou, et al., 2013). Coordinated efforts are not in place due to the international dimensions of marine ecosystems, a lack of data and understanding on these ecosystems, as well as the limited experience with formal initiatives. Mayer et al. explain why gaming would be relevant for MSP:

> *The foremost challenge posed by MSP involves governing complex maritime and ecological systems that are linked to several policy arenas…Given its high level of sociotechnical, multi-actor complexity, MSP can be portrayed as a 'strategic game' with interdependent players, stakes, objectives and resources, in addition to multiple rounds of decision-making, characterized by a high level of strategic behaviour. To promote understanding and change in such situations, the actual strategic game can be created (or re-created) and modelled in the form of a simulation game or serious game* (pp. 8-10).

With this in mind, the researchers created a game called *MSP Challenge 2011* with the objective to contribute to the learning process of an ecosystem-based, integrated and participatory MSP. As part of this contribution, the game has three combined functions: 1) Policy-oriented learning: teaching players about the complexity of MSP as well as encouraging them to try out strategies and gain experience; 2) tool validation: test a prototype of an interactive tool; and 3) policy research: gain insight into the backgrounds, frames of thinking, and solutions of MSP experts. Although the game is primarily developed as educational tool, it has two important assessment functions: one of the technology and one of the people involved and what they produce.

The game is focused on four countries around a single shared sea area. A computer tool with an interactive map with seventy-five layers of spatial information represents this semi-fictional area. Examples of spatial information are the location and characteristics of oil and gas infrastructures, commercial fishing, and marine protected areas. The game is semi-fictional because it is based on real data, yet the designers simplified, abstracted, and reduced this data ‘to create a level playing field and make it manageable and educational’ (Mayer, Zhou, et al., 2013, p. 11). Each country has various stakeholders: planners, companies, NGOs, and policy analysts/scientists. Each stakeholder is represented by two to five players, who get a country-specific profile containing goals and objectives. Designers aimed for deliberately creating a realistic and ambiguous policy setting by ensuring for information overload and asymmetry and introducing vagueness, ambiguity, and imperfect information. No player in the game is neutral, not even the scientists. They all (should) act according to their interests, as described in their role descriptions. The planners in the game are tasked with the most difficult challenge: to get a MSP ready for their country. At the end of the game, the players assess the spatial plans from the other countries, using criteria from the European Union principles.

MSP Challenge 2011 was played with 68 MSP experts as part of a 2.5-day conference workshop. Data were gathered through pre-game, in-game, and post-game observations with various methods: interviews, questionnaires, game logs, and video recordings. A general consensus was that the game helped to get the ‘big picture’ and fostered ‘systems thinking’. In addition, the log data clearly showed that participants tried out various strategies, thereby providing evidence that the game achieved its primary purpose. In terms of assessment, the game made clear that a need exists to reflect on the variety among stakeholders for integration to happen. The assessment tools provided by the game can help facilitate such a process. Relationships between process and outcomes became visible too, possibly indicating that predictions can be made based on how players are managing the process. Although it is difficult to measure impact on the actual planning processes, the researchers note several initiatives for cross-border collaborations on MSP and improvements in ICT tools after the game. The most evident measure of success, however, is that an improved, second version of the game was played again, this time called *MSP Challenge 2050*, in 2014.

X.4 Designing games

With all of the above we have provided an overview of gaming and detailed its application to environmental issues specifically. We will now turn to providing the 'how to' part of this contribution, and start with explaining the design of games. Many books have been written on this topic. Although many practitioners will say they have never read any and that it is best to simply start making them, a few books exist that are worth consulting before, during, and after being engaged with designing games (Fullerton, Swain, & Hoffman, 2008; Salen & Zimmerman, 2004; Schell, 2008). One reason why practitioners provide this advice is that game design is a skill that is mastered through experience. It cannot be learned from reading or hearing about it. While doing it, it is further difficult to tell what will be the right approach and what design decisions need to be made. It is and remains a creative effort that cannot be optimized by considering all the constraints, such as budget and the requirements put forward by clients or publishers. The best possible way to deal with the uncertainty is to test the design with players and refine it based on their feedback. Such an *iterative* approach is a crucial part of any successful game project.

One important reason why testing (as discussed also later in this chapter) is of such importance is illustrated by the well-known Mechanics, Dynamics, and Aesthetics (MDA) framework (Hunicke, LeBlanc, & Zubek, 2004). Mechanics are the base components of the game as formalized by the designer: the rules, algorithms, and actions players can take, etc. Dynamics is what happens when the game is played. It refers to how the mechanics act out amongst each other and in relation to player input. Upfront it is often hard to predict how the dynamics play out, due to the difficulty to predict what players will do and how the various mechanics interact. This is best observed 'in action', by having actual players test the game. Finally, aesthetics are the emotional responses evoked in the player, such as joy and frustration. These responses, which serve as (dis)confirmation of the quality of a game, can only be retrieved by having participants test the game. A common advice in the games industry and academia is to test early and often. Fullerton et al. (2008) advise to start with what is known as *paper prototyping*, low-tech (or even no-tech) iterations of the design to get a sense of how the game works.

The design of serious games is different from entertainment games. This is best explained through the Triadic Game Design (TGD) philosophy (Harteveld, 2011). According to TGD, designing a serious game revolves around three 'worlds': Reality, Meaning, and Play. When we talk about games with a serious purpose, we talk about games that are based on and/or should have an impact on the real physical world. It is, however, not sufficient to only consider our 'reality'. It is also required to consider how such an impact can be achieved. The game should have some 'meaning' beyond the game itself and for this to happen, designers have to think about how this could take place. Finally, the third world has to do with the medium itself. A game is a tool or medium that is constituted by 'play'. It involves make-believe, competition, engagement, rules, and all other aspects that are characteristic to games and not to other sorts of tools or media.

The three, Reality, Meaning, and Play, are called worlds, because each one of them is related to different disciplines, ways of working and thinking, and can be represented by different people. Furthermore, each world sheds light onto a game in a different way by using theories, practical examples, or even attitudes and beliefs. Another way of putting it is to say that each world is a perspective that can be used to look at a game. To elaborate on these worlds specifically, a short description of each world is given below:

- **Reality:** Games have always – however abstract they may be – a relation with the real world (see our discussion on the affordance of models and simulations). If it is about games with a serious purpose this connection should even be tighter, because in the end the real world needs to be affected by the game. Reality could be represented by stakeholders (with their expertise and opinions) from the real world or can be seen as a representation of the real world inside the game. The world Reality thus represents the real world and its model representation – the 'model of reality' – in a game. It is grounded in the disciplines related to the subject matter. People affiliated with this world are subject-matter experts in the domain of the game (e.g., geotechnical engineers).
- **Meaning:** No game can be considered 'meaningless'. Games, like other media, can have a profound effect on society at large and can be seen as cultural expressions in their own right. Players will also definitely learn something in each game, whether hand-eye coordination skills, visual-spatial skills, or an idea of how ancient Rome may have looked. However, to intentionally achieve a meaningful effect beyond the game experience, something that is useful in the real world, a more elaborate consideration needs to be made of how this can be achieved. The world of Meaning is concerned with this creation of value. It is related to disciplines, such as the learning sciences, psychology, and communication studies. It is the world of subject-matter experts in the purpose of the game (e.g., learning scientists).
- **Play:** Aside from being related to a real world and having meaning, games are first and foremost a specific tool (or medium). Each tool has its own specific characteristics. When we think of games, we think of highly interactive and engaging tools that immerse people into a fictive situation. This can range from simple point-and-click adventure games to grand-scale virtual worlds with thousands of active players. This world is affiliated with disciplines as game design and Human-Computer Interaction. This world is related to game designers and artists.

One of the reasons that serious game design is different is that each of the aforementioned is equally important and has to be taken into consideration. This requires designers to ‘balance’ the three worlds, as each makes different demands on the design process. This act of balancing is difficult because tensions may arise that force designers to make trade-offs or find ways to resolve design dilemmas. In navigating this design challenge, TGD may offer a way of thinking that helps to become aware of the various needs and to put everything in the right perspective. There are no cookie-cutter answers to finding such a balance. As with entertainment games, the best approach is to test and reflect on the results. Due to the importance of testing in game design, we are devoting in the next section significant attention to this part. However, one recommendation for ensuring a successful project is to have the different worlds represented throughout the entire design process. This is best accomplished through different representatives that act as gatekeepers to defend their interests, e.g. a geotechnical engineer explaining the game designer that a levee failure with eyes and a mouth will not be appropriate.

Another point is that the design does not stop with creating the game itself. The context in which the game is used and additional material will have to be considered to make a lasting impact. Therefore, game design involves designing ‘gaming’, not only a game. The entire activity, from beginning to end, will have to be considered. This design principle has been referred to as ‘big fish in a big pond’ – although the game is still important, the surrounding environment is important too (Harteveld, 2012). A crucial element in designing that environment – especially for educational implementations – is *debriefing* (Crookall, 2010). Debriefing happens in between or after playing the game and is done to let players reflect on their experience. It stems from experiential learning theories, where the reflection stimulated in debriefing turns ‘spontaneous concepts’ acquired during the experience into ‘scientific concepts’. In other words, debriefing is what helps to make the point come across, to solidify the learning. It depends on the type of game, but other gaming elements include accompanying instructional material and lesson plans.

X.5 Evaluating games

In the above sections we have described how games applied to study and educate in environmental contexts have originated, and been used, in different contexts and situations. We have also briefly outlined how game design operates. A vital consideration when employing games for research or educational purposes – similar to commercial games in general – is to be able to evaluate the effectiveness of the game design, not just in terms of any learning outcomes and results, but also in terms of the user experience and the effectiveness of the games' design. In this section we outline the approaches employed for evaluating games. The main focus is on user-focused evaluation, notably towards evaluating user experience, behavior and learning, which is more relevant for gaming as intervention tool. Evaluating gaming as research method in its own right will not be covered in detail. The reason for this choice of focus is simply that the users (players) are alfa and omega to the success of games. Ensuring an engaging user experience is central to game design – whether for entertainment or serious purposes. That said, many of the discussed methodologies can be easily translated to be used for a more systems-focused evaluation.

Within the umbrella of user-focused evaluation, a specific focus is on quantitative analytics approaches that utilize behavioral telemetry and have their roots in business intelligence. These methods jointly fall under the domains of Game User Research (GUR) and Game Analytics (GA). The distinction between these two is somewhat nebulous and often used interchangeably. They are discussed in more detail below. This specific focus has been chosen based on the paradigm shift that has occurred in the commercial game industry in recent years towards data-driven design and evaluation. This shift has set a trend that has impacted educational games and the use of gaming as research method as well (e.g., Harteveld, 2012; Shaffer & Gee, 2012). Second, in evaluating games any methodology and set of accompanying methods can be employed: ethnography, interviews, questionnaires, standardized tests, etc. The variation among the discussed evaluation approaches of the detailed examples *EnerCities*, *Levee Patroller*, and *MSP Challenge 2011* illustrates this. Although still in its infancy in use and specification, games have an intrinsic data collection method, and therefore it seems logical to focus on this capability specifically. Third, we believe that analytical approaches based on game telemetry are important for gaming to mature and to be used as a structural tool for researchers and practitioners (see also Seif El-Nasr et al., 2013).

In this section we start by explaining GUR and the various evaluation strategies employed in this field. As argued above, we then narrow our focus to the evaluation strategy of behavioral analytics. The starting point is the current state-of-the-art in the game industry, where most of the advances are currently being generated, but with perspectives from academia as well.

X.5.1 Evaluation strategies

The area of Game User Research (GUR) has emerged over the past decade as a sub-field of research within the Human-Computer Interaction (HCI) community to address the specific problem of user-oriented evaluation of games, or more specifically of the interaction between player and game (Isbister & Schaffer, 2008). From the perspective of GUR, the fundamental challenge game evaluation deals with is *user experience* (UX). Without an engaging experience, players will stop playing or get frustrated. This holds true for any game, whether a strategic planning game such as *SimPort*, or a simple casual mobile game (Pagulayan, Keeker, Wixon, Romero, & Fuller, 2003). This supreme role of what is also referred to as *Player Experience* (PX) sets games apart from other applications and for consideration of conventional evaluation methods.

In GUR, the focus has been on adopting and adapting methods and techniques from outside the games domain to work within the games context. This is notably an issue that the games industry has been working on (Pagulayan et al., 2003; Southey, Xiao, Holte, Trommelen, & Buchanan, 2005; Zoeller, 2013). The existing work found that relying on relative simple measures of PX, e.g. a pop-up survey during play-testing asking people to rate the game on a scale from 1-5 depending on how fun it is, works fine for getting an overall idea of PX, despite the inherent limits of this kind of measurement strategy. In addition, it is an efficient and still effective way of performing play-testing (Kim et al., 2008; Medlock, Wixon, Terrano, Romero, & Fulton, 2002). Three fundamental approaches exist to user-oriented testing of games, all of which are adapted from test methods in the general IT sector and business intelligence:

- **Usability testing:** Focuses on measuring the ease of operation of all elements of the game, including controls, GUI, menus and gameplay mechanics.
- **Play-testing:** Explores whether users have a good experience and aims at detecting problems in the game design that can impact the experience negatively. In this type of testing, learning can also beevaluated (Desurvire, Caplan, & Toth, 2004).
- **Behavioral analytics:** Explores the user from a strictly quantitative perspective via behavioral telemetry, focused on detecting problems to the game design, the user experience, progress through the game or detecting subversive behavior, e.g. use of bots or gold farming in massively multi-player online games. The approach can also be used to look at system behavior (i.e., game plus player).

Play experience data generated during usability testing or play-testing are generally obtained using qualitative or semi-quantitative methods, such as observation, interviews or surveys. Notably attitudinal data (users expressing their opinion about something, e.g. how much fun they are having, which elements of the game that are too hard, etc.) are commonly collected, across any of these methods (Pagulayan & Keeker, 2007; Romero, 2008). In comparison, analysis of behavioral telemetry data offers insights into how the users are actually playing the games being tested, but not play experience. This makes telemetry testing an ideal candidate for triangulation with usability- and play-testing.

All three approaches are of importance to the successful development of a game. This stage of evaluation is commonly referred to as *formative assessment*. It is a stage of development, where the evaluation results will be fed back into the development. For *summative assessment*, which focuses on measuring outcomes (i.e., whether the purpose has been achieved), the quick-and-dirty approaches from the industry do not suffice. More rigorous methods and intensive evaluation procedures are needed to retrieve compelling evidence. To this date, no standards exists, except for a few attempts on creating validated PX questionnaires (e.g., Brockmyer et al., 2009; Norris, Weger, Bullinger, & Bowers, 2014), and even if they did, games would need to have customized methods based on their purpose, domain, and type of game, among others.

For serious games in general, the industry methods would be considered lacking in breadth and scope. To use the terminology of Triadic Game Design (Harteveld, 2011), the industry evaluation strategies are in particular focused on the world of Play, and ignore much of the worlds of Reality and Meaning. Unfortunately, this does mean that for evaluating serious games many aspects have to be considered, which often leads to forced trade-offs due to time constraints and participant fatigue. This makes less obtrusive and more intrinsic measures such as those provided by behavioral analytics promising and this is another reason for why we are focusing on this type of evaluation in this contribution. It is, however, important to keep in mind that behavioral analytics are not a golden solution. Triangulation with other methods would be desirable. In addition, during early stages of the development, usability testing and play-testing are incredibly important and more efficient.

X.5.3 Game analytics and game telemetry

In recent years, the tracking and logging of telemetry data has become widespread in the digital entertainment industry, leading to a wealth of incredibly detailed information about the behavior of – in the case of popular entertainment titles – millions of players and installed clients (Sifa et al., 2014). This practice forms part of the domain of Game Analytics (GA) (Seif El-Nasr et al., 2013). From the perspective of the game industry, telemetry is data collected about any process or aspect of game development, including information about the operations of technical infrastructure, game production and – processes, post-launch management of games, quality assurance and perhaps most importantly: behavior of users playing the game and the resulting system behavior. In any of the data collection processes, game telemetry data are the raw units of data that are derived remotely, e.g. from an installed game client or game server (Seif El-Nasr et al., 2013).

Raw telemetry data can be stored in various database formats, which are ordered in such a way that it is possible to transform the data into various interpretable measures, e.g. average completion time as a function of individual game levels. These are called *game metrics*. Game metrics are interpretable measures of something, whereas telemetry is the raw data that we work with. The term game metrics is often used as a synonym for game telemetry data, but to be precise, metrics represent telemetry data that have been transformed somehow (see below).

The vast majority of the work being done in the industry and game research using game metrics has been focused on the users, from the dual perspective of players being: a) *Sources of revenue* (e.g. churn analysis, average revenue per user, micro-transactions); and b) *Customers* who behave in a particular way when playing games (e.g. playtime, time-spent analysis, asset use evaluation, path (trajectory) analysis). Less emphasis has been placed on game metrics as a source of information on the production process itself, i.e. technical, infrastructure, support and production metrics, although this appears to be changing (Mellon, 2009). A third common, and also less emphasized viewpoint is the system perspective, where the interaction between the game system itself and the players is the focus of investigation. An example is the evaluation of the player interaction with artificial (AI-driven) agents.

Behavioral game metrics form the basis for telemetry-driven user experience evaluations, forming measures of player behavior, e.g. navigation, item- and ability use – any action the players perform inside the virtual environment of a game (whether 2D or 3D). Another term commonly used for these kinds of game metrics is *gameplay metrics***,** denoting that they specifically relate to measures of user behavior. Any measure of player behavior inside the game environment, e.g. object interaction, object trade, navigation, player-player interaction etc., is a gameplay metric.

Gameplay metrics are the most important form of game telemetry when the purpose is to evaluate user experience and game design in general (notably for "debugging" the playing experience), but are also furthest from the traditional perspective of the revenue chain in game development, and hence are generally under-prioritized (Drachen & Canossa, 2009; Isbister & Schaffer, 2008). In contrast, gameplay metrics should be over-prioritized for gaming as intervention tool and research method.

X.5.4 Game analytics in practice

Behavioral metrics form the basic pieces of information for working with telemetry data from a game design angle, and it is often in the gameplay metrics that we find the root causes for observed player behaviors (Kim et al., 2008; Zoeller, 2013). For example, this could be about finding that a specific level segment is too difficult and causes players to quit the game; that a specific item is not being used by the players; or that the solar cell technology is overpowered and makes it too easy to win in an energy-themed game, etc.

Drachen, Canossa, and Sørensen (2013) provide an overview of the fundamental approaches to working with behavioral game telemetry that will be described here: The authors, writing from experience with fielding telemetry analysis at the game companies IO Interactive and Crystal Dynamics, noted behavioral analysis is typically either performed via *analysis* or *synthesis* – both classic scientific methods. They are different, but in practice this difference can be subtle and they often go hand in hand: *Analysis* is when we break down a complex whole into parts or components. For example, when we break down the action-sequences of the players in a time spent analysis. *Synthesis* is the opposite procedure, i.e. combining separate elements or components in order to form a coherent and complex whole. For example a chart showing the number of daily active users (DAU) is a synthesis of time, number of users, date, etc. The system suggested by Drachen et al. (2013) provides guidance on planning how to answer particular problems – e.g. considering whether a problem is best solved analytically or using simple synthesis, whether we already have an idea about what the answer is and should test it, or not – and so forth.

Both analysis and synthesis can be initiated by fairly open-ended (do our players finish the game? Do they learn anything? What decisions do they make?) Or specific questions (does that player cheat by using the bug that makes the solar panels yield too much energy?), roughly correlating with the concepts of explorative vs. hypothesis driven research from scientific theory. What this means is that the analytical methods we use to find the answers to questions are either of a type where we are looking to confirm some idea we have and are looking for confirmation, or have a pretty good idea about the possible answers (*hypothesis-driven*); or more open, where we are not sure what the answer to a given question is, or have a hard time predicting the possible answers (*explorative analysis*). Both synthesis and analysis can be applied to explorative work (where we look for patterns in data) or hypothesis-driven work (where we have an idea what the answer is and need to confirm or reject the idea). Based on this, we can distinguish two types of inquiries when engaged with behavioral analytics:

1. **Explorative metrics work** is when the possible answers cannot be, or are hard to predict from looking at the game design. For example, finding which types of rewards that are the most important drivers for ensuring that players are motivated progress between game levels. A common data-driven method for explorative research is the drill-down analysis, where the gameplay metrics data are examined at more and more detailed levels until an answer is found.
2. **Hypothesis-driven metrics work** is when we are looking to confirming conclusions or ideas, or when we can predict the answer. For example, it may be believed that nuclear power plants make it too easy to provide energy in a resource management game. Performing an analysis on this question in order to confirm this suspicious will lead to either support for the hypothesis being true or the opposite. Hypothesis testing in practice often leads to new questions and new hypotheses, due to the complexity of evaluating human behavior in games.

In practice, as soon as moving outside of the kind of questions that can be answered with synthesis, a quick analysis or standard algorithms, e.g. 'what is the number of active users today?' or 'what is the average playtime for level 22?', a mix of hypothesis-driven and explorative work is needed. Explorative questions are usually more time-consuming to answer and more often require analysis than the hypothesis-driven, specific questions, which can more often be handled using synthesis (or very simple statistical analysis) of the relevant data. For this reason, game companies rarely perform purely explorative questions. They cannot justify the time and costs for such inquiry.

The description of explorative/hypothesis-driven methods is only descriptive in terms of the fundamental approaches to working with behavioral game telemetry. These methods are set in the broader contexts of the game development process, and notably game user research. However, as we hinted at repeatedly throughout this chapter, they are promising evaluation methods when considering gaming as intervention tool or research method, in the context of environmental issues and beyond. For researchers, these methods allow for testing and building theory about human and system behavior, as well as for assessing player learning and decision-making. Even without large participant numbers, it provides opportunities that might be difficult to realize in the physical world. The reader is referred to Isbister and Schaffer (2008) and Seif El-Nasr et al. (2013) for more detailed information on this topic, but in brief, the application of behavioral telemetry to solve a problem follows the standard process for knowledge discovery in data (Berry & Linoff, 1999; Larose, 2005).

X.6 Trends and challenges

In this chapter the motivation for the use of games and gaming within the domain of environmental issues has been briefly outlined, and an array of associated topics covered, not the least design and evaluation of the games themselves. In this final section, we summarize and round off the chapter by providing a condensed discussion of some of the primary trends and challenges associated with using games – whether for awareness, data collection, or any other purpose – in the context of environmental studies and beyond.

In terms of the state-of-the-art of the overall field of serious games, this has been partly covered in the above sections. As discussed, the current application of games for serious issues is incredibly diverse and technologically (e.g. in terms of hardware platform) and topically widespread. For environmental issues specifically, the currently available games range from simple web-based games from various organizations and e.g. national weather or –environmental services, all the way to online, multi-player games, and complex non-digital games requiring a dozen or more players aimed at engaging real-world stakeholders in decision-making processes. Amongst this diversity, we noticed a few trends in the application of games, notably:

1) **A new dawn for citizen science:** It is becoming increasingly popular to tap into the ‘power of the

crowd' to drive research results. In terms of game-based citizen science, this is currently happening mainly in medicine and chemistry, but increasingly across a variety of topics (Prestopnik & Crowston, 2011). The potential for adopting citizen science in environmental studies is not new – consider for example the use of networks of volunteer observers (see also Ellis & Waterton, 2004; Krasny & Bonney, 2005; Silvertown, 2009) – but with new technologies such integration of citizens into environmental issues research has become easier and more scalable, as illustrated by *YardMap*. We expect that rather sooner than later game-based citizen science will blossom for environmental studies.

2) **Large-scale and networked player populations:** The ability of networks to connect people online and through a variety of platforms also comes into play in connection with games. Single games are today played by potentially millions and in some cases hundreds of millions of people. As serious games mature, they will increasingly seek to and be successful in tapping into large-scale populations. This has direct implications for not only citizen science projects but also those seeking to educate or raise awareness.

3) **Analytical tools simplifying data capture:** As has been highlighted in this chapter, tracking player behavior in games is a promising affordance to evaluate games, irrespective of their purpose. In digital games, tracking the second-by-second behavior the players has become increasingly easy thanks in part to a variety of tools developed for this purpose. This has given researchers and designers powerful new tools for evaluating designs, learning, and decision-making.

4) **Blending of digital and physical worlds:** The arrival of Alternate Reality Games (ARGs) has blurred the boundaries between games and the physical world. We will increasingly see more linkages, much fostered by developments as gamification (i.e., the use of game elements in non-game contexts) and (big) data access and visualization. The simple games developed using Google Earth for guessing locations are just a glimpse of what we can expect in the future.

5) **Games as research platforms:** The idea of performing meaningful behavioral research via the

Internet (Birnbaum, 2000) is but only one step away from harnessing digital games for this purpose, with all the added advantages listed in this contribution. Although using games as a research platform is increasingly done (Crandall, Klein, & Hoffman, 2006), so far this use remains very limited, most likely because of the challenges in getting this right. Skepticism also exists, but this will change along with empirical results and by the increasing digitization of our daily life. Many operations, including weather services, are done behind the screen of a computer or mobile device.

In addition to the current trends, it is necessary to highlight a couple of the most crucial challenges facing the use of games:

1. **Creating a balanced game design:** Game design is by no means a straightforward process, and requires specialized knowledge. Designing a game for entertainment is challenging in its own right. Designing a game that is both entertaining (so as to attract and retain players/participants) and achieves a meaningful purpose on a real world topic, is even harder. Finding a balance in reconciling these objectives for a successful project is perhaps the key challenge. We recommend an interdisciplinary collaboration between game design experts and subject-matter experts (on the game's purpose and domain) from start to finish.
2. **Attracting players or participants**: Even though technology has progressed to a point where in practice it is possible to attract large numbers of participants, this is by no means an automatic process. Players need to be aware of the existence of the game, be motivated to seek it out, and subsequently the game needs to be engaging to ensure that the participants complete it/provide useful feedback. For games that have to be played in a physical location, the challenge for attracting players is in organizing game sessions. Physical or digital distribution, in either case we recommend that design teams consider marketing and distribution strategies early on to enable the possibility to integrate elements into the design that will increase the game's success.

3. **Evaluating games rigorously:** The central challenge in evaluating games is that there is no established, rigorous way to do so. There is no standards association providing guidelines and there are few, if any, books to consult on how to find out what information to collect for evaluation purposes and how to do this in practice. Although much has been written about the evaluation and user-testing (including usability, user interface design and more) of commercial games (e.g., Isbister & Schaffer, 2008; Kim et al., 2008; Seif El-Nasr et al., 2013), the material remains somewhat fragmented. This is an even larger problem in serious games, where evaluation techniques are less developed and even more fragmented, and the empirical evaluation of the actual impact or validity of the results remains debatable. We recommend to recognize a need for rigor, and consult possible similar studies or early attempts at establishing methodologies (e.g., Mayer, Bekebrede, et al., 2013).
4. **Dealing with player behavior**: An important assumption of especially the use of gaming as research method is that player behavior is equivalent to that of how a player-person would behave in the real world. Although significant research has been done where behavior in virtual worlds is linked to that of the real world (e.g., Blascovich & Bailenson, 2011), this assumption cannot always be assumed. In fact, players may act out very differently, due to the affordances that games offer and depending on their play history and preferences. In addition, various game tropes and traditions have emerged that may influence how players experience the game and/or what they expect from it. For this reason, player behavior has to be scrutinized and the design process should carefully consider what aspects may induce potential bias.
5. **Measuring user experience:** This challenge partly overlaps with the problem of evaluating games, but is specifically focused on the problem of measuring user experience in an effective, reliable and inexpensive way. Given the importance of user experience to games, it is perhaps not surprising that this is a topic that has seen a substantial amount of interest in the industry and associated academic areas. There are at the time of writing no standards to adhere to, and user experience (or more specifically player experience) in games are currently evaluated using a

variety of techniques, from interviews, surveys all the way to advanced psycho-physiological methods such as fMRI scanning. For any serious game, the central challenge remains to develop a way to embed user experience measures in an effective way in the user testing process. Some frameworks currently widely used in the industry are discussed by Isbister and Schaffer (2008) and Rigby and Ryan (2011). Both of these volumes are good introductory texts. With the emergence of the tracking of player behavior telemetry, this data source is increasingly seeing application in user experience evaluations also (notably to map user experience issues with specific events or areas in a game). The emergence of game analytics may someday lead to automated ways of detecting user experience (e.g., Canossa, Drachen, & Sørensen, 2011), but this is as yet in the future.

Our key advice to those interested in using gaming on environmental issues, however, is to go out and start doing it with the following mantras: embrace failure and test often. As with any good game, one will learn from trial-and-error and this requires testing often and failing just as much. Although it is an unpleasant process, one should always keep in mind that it is better to fail in making a game than to fail in dealing with environmental issues.

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