Disaster realities in game world

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Abstract

Since the 1970s serious games have been used to simulate real-world topics to facilitate learning, business training and government-related activities. Over the past decade, the application and popularity of serious games expanded to raising awareness on disaster risk reduction (DRR) concepts. This study takes a different path in addressing a gap in the literature by conducting a more in-depth analysis of how ten non-commercial disaster serious games frame six fundamental concepts of disasters. The study utilised a disaster risk mnemonic and serious game design framework to dissect and demonstrate how both DRR concepts and game elements portray disaster and DRR realities to its target layers. These realities can become sources of knowledge and potentially influence disaster-related actions. The researcher employed an interpretative constructivist approach to draw empirical findings from the game artefacts. The content analysis of four-game layers iterates the benefits of serious games outlined since the 1970s and re-echoed by recent DRR serious game studies. The study, in particular, underscores that all games follow a hazard-focused game storyline. Therefore, hazard acts as a vehicle to introduce other dimensions of disaster (i.e. vulnerability, capacity) and DRR measures (i.e. disaster prevention, mitigation, preparedness). Thus, the game world portrays disaster as an event and undermines the social processes which account for most disastrous outcomes. The games, however, did not fail to demonstrate significant risk reduction through the concept of capacities and DRR measures which were represented in different levels (i.e. individual, household, community-at-large). Furthermore, most of the games were successful in simulating altruism, different patterns of access and resources which are weaved intricately into game scenarios and gameplay.

Overall, the empirical findings of the study pose a challenge to professions within the disaster serious game community to map realities portrayed by existing disaster serious games. Academics and game designers, therefore, may utilise the same methodological approach employed in the study to harmonise understanding of both worlds. The disaster mnemonic structures how six fundamental concepts of disaster relate to each other; the serious game design framework, on the other hand, outlines game layers where DRR concepts are injected to create a player experience. Hence, both frameworks provide a common language to maintain and reshape features or intentions of disaster serious games. Lastly, the findings of the study encourage game designers to collaborate with social scientists and vice versa to create vulnerability-inspired storylines. Doing so reclaims the ability of serious games to contribute to government-related activities and potentially valorise local capacities enacted to reduce vulnerabilities.

Dedication

To all kindred souls who believes in the power of gameplay

Acknowledgement

My journey in completing this thesis and master's degree was not a walk in the park. Hence, I would like to give all glory and praises to God for His immeasurable guidance and love that gave me the strength to surpass both personal and academic challenges successfully. Also, I believe His blessings manifested through institutions and people of which I would like to convey my sincere thanks in this writing.

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1. Serious games in disaster risk reduction

Disasters feature popular culture in multiple forms (e.g. games, movies, folk legends, jokes, memorial services). Webb (2007) categorises all these disaster-themed products (both material and non-material) as part of disaster popular culture (DPC). Formal accounts about DPC date back to the 1950s and highlighted the importance of looking into [popular] culture (e.g. folklore, songs, arts) and its role in capturing people's response to disasters (Quarantelli & Davis, 2011). Subsequently, a momentum of research studies emerged analysing a range of DPC products. Some of these studies analysed disaster-themed songs (Cosgrave & Kelman, 2017; Alexander, 2011), films (Berger, & Wisner, 2011), video games (Gampell & Gaillard, 2016; Gampell et al., 2017; Solinska-Nowak et al., 2018; Gordon& Yiannakoulias,2020).

This research takes a particular interest in analysing disaster serious games. Abt (1970) and Aldrich & DiPietro (2009) categorise games designed for learning as serious games. Hence, disaster serious games encompass disaster-related concepts such as hazards, vulnerability, capacites and disaster risk reduction (DRR) measures (i.e. disaster prevention, mitigation and preparedness) intricately weaved into gameplay. For the last decade, there has been a steady rise in popularity and use of games as a tool for raising awareness for DRR (Tsekleves et al., 2016; Gampell et al., 2017; Solinska-Nowak et al., 2018). The recent study of Solinska-Nowak et al. (2018) provides empirical evidence that serious games have been widely used in various settings (e.g. community awareness, training) to raise awareness on disaster-related concepts for a diverse set of stakeholders (i.e. children, teenagers, adults of different professional background). However, despite the increasing popularity of games, there remains a paucity of research exploring their impact in terms of DRR.

Most of the studies on disaster-themed serious games, however, put great emphasis on analysing their potentials, effectiveness and impact as a tool in disaster education (Di Loreto et al., 2012; Gampell et al., 2017; Solinska-Nowak et al., 2018). This research takes a different path and focuses on how non-commercial serious games (digital & analogue) frame fundamental concepts of DRR. These concepts—hazard, disaster, vulnerability, capacity —are used to inform DRM measures (i.e. disaster prevention, mitigation and preparedness). This study argues that, in order to build evidence and reshape gamification of DRR concepts, we must first step back and analyse how the game world represents these concepts. Furthermore, it is imperative to analyse how games extend disaster realities because sources of knowledge can potentially affect the decisions and actions of stakeholders of DRR (Mercer,2012).

Given these points, the section below details the questions that the study aims to answer:

1. What are the goals of disaster themed serious games?

2. What dimensions of disaster are commonly represented in disaster themed serious games?
3. What kind of DRR initiatives do disaster themed serious games promote?

This thesis, therefore, is divided into six sections that outline the intersection of DRR concepts and game elements. The following section provides an overview of both DRR and game world to introduce why disaster is both an event and a process and the fundamental concepts that frame DRR. In addition, the same section outlines the concepts and frameworks of the game world to understand the concepts and processes that enable games to harness and reinterpret realities in different scales. The third section discusses the constructivist approach that the researcher used to capture and interpret disasters in games. The fourth section focuses on how ten non-commercial disaster-themed serious games frame fundamental concepts of disaster and DRR using Wisner et al.'s (2011) DRR mnemonic and Winn's (2009) Design, Play and Experience (DPE) framework. The fifth section compares the disaster realities from the ten disaster-themed serious games and what the existing literature says about the concepts of disasters and DRR Finally, the study concludes that it is difficult to harmonise DRR concepts and game elements. Thus, drawing from the implications of the analysis, the conclusion attempts to recommend a research agenda and suggestions on how one could gamify DRR in the future.

2. Literature Review

2.1. Fundamental concepts of disaster risk reduction

Defining concepts that frame the world of disaster studies is an arduous task. These concepts are overlap and constantly evolve and have been subject to much interrogation by academics and practitioners alike (Serje, 2011; Wisner et al., 2011; Twigg, 2015; Gampell, 2016). Disaster studies includes the concepts of hazards, vulnerability, capacities, all of which are strongly used in structuring disaster risk reduction measures (Gaillard, 2010). Considering the rich and diverse interpretations of these concepts, the definitions presented in this section are by no means exhaustive.

Wisner et al.'s (2011) expanded mnemonic on disaster risk provides a framework for discussing the concepts of hazard, vulnerability and capacities. These concepts are components that define what a disaster. The expanded version follows a pseudo-equation:

$$DR = H \times [(V/C)-M],$$

Here, *DR* stands for disaster risk, *H* is hazard, *V* is vulnerability, *C* is capacity and *M* is large-scale risk mitigation through preventive action and social protection (Wisner et al., 2011). It is important to

emphasise that this mnemonic intends to expose the correlations of the different concepts and must not be treated as a mathematical equation.

The concept of hazard gives rise to a dominant view or paradigm of disasters as an event. Disasters, therefore, happen within a specific time and geographic boundary and undermines "what came before or after" the particular event (Bankoff, 2011). Hence disasters result from people's inadequate perception of risk associated with these extreme natural events (Gaillard, 2010). For example, the strong winds, torrential rains and storm surges associated with Super Typhoon Yolanda wreaked havoc across parts of Eastern Visayas at 4:40 am on November 8, 2013. The hazard paradigm, pioneered by White (1945) and Burton and Kates (1964), would utilise probabilistic models and technological devices to understand, monitor and predict this natural event. This paradigm links the causality of disasters with rare and extraneous elements (physical characteristics) of a natural hazard. Table 1 provides a general classification of hazards adapted from Wisner et al. (2011).

Table 1. Typologies of hazards (adapted from Wisner et al., 2011)

Hazard category	*Origins*	*Examples (not a comprehensive list)*
Hydro-meteorological/ climatological	Hazards from water, weather and climate	Avalanches, climate change, drought, floods, fog, glacial surges, hurricanes, icebergs, lightning, precipitation (e.g. freezing rain, hail, ice, rain, sleet, snow), storm surges, temperature extremes or fluctuations (cold and heat), tornadoes, waves, wildfires and wind.
Geophysical	Hazards from geology	Earthquakes (and associated hazards such as tsunamis and landslides), erosion, landslides/rockslides (and associated hazards such as tsunamis), poison gas, sandstorms, soil loss and contamination, volcanoes (and associated hazards such as fire, fumaroles (gas emissions), lahars (mudflows), jökulhlaups (glacial floods), tsunamis and vog (volcanic fog)).
Biological/ ecological	Hazards from living organisms or ecosystems	Wildfires, microbial pathogens, and poisonous, aggressive or otherwise dangerous plants and animals.
Astronomical	Hazards from outside the earth	Space weather and collision or near-collision of celestial bodies (e.g. asteroids and comets) with the Earth and associated hazards (e.g. tsunamis, wildfires).

The concept of vulnerability, on the other hand, emphasises that the hazard is only the tip of an iceberg as one tries to trace the causalities and realities of a disaster. The concept and paradigm of vulnerability in disaster studies was coined and pioneered by prominent scholars such as O'Keefe et al. (1976), Wisner et al., (1977) and Hewitt (1983). This paradigm views disaster as a process and explores the root causes of vulnerability (Bankoff, 2011). Local people indeed have minimal control on the processes that create vulnerabilities (i.e. power, political and economic systems) (Wisner, 1993; Twigg,

2015; Gaillard 2007; Gaillard, 2010; Kelman et al., 2017). These external forces often result in and exacerbate chronic marginalisation of local people which impedes access to essential resources (e.g. food, water safe housing and infrastructure, education), social protection mechanisms (e.g. health benefits and services,) and social networks (Wisner, 1993; Cannon, 1994; Wisner et al., 2003; Gaillard & Mercer, 2013). Hence, vulnerability is multi-layered and multidimensional (Watts & Bohle, 1993). The concept is often used to best describe and explains "who suffers in a disaster" (Anderson & Woodrow, 1991, p.45) and accounts for the most disastrous outcome (Cannon, 1994).

The concept of capacities emerged as a result of a growing, and steady recognition of local people as knowledgeable and resourceful (Freire, 1970; Chambers, 1983; Cannon et al., 2003; Mercer, 2011; Gaillard & Mercer, 2013). Gaillard et al. (2019) define capacities as the "diverse knowledge, skills and resources people can claim, access and resort to in dealing with hazards and disasters." (p.863). The authors highlight that capacities are not necessarily place-based as evidenced by migrant remittances, highlighting that people can support each other remotely. People enact and utilise capacities individually and collectively as part of their everyday lives and in different contexts. This definition of capacities echoes 50 years of empirical evidence in social science research that debunks disaster myths such as chaos, panic, social indifference and looting; instead, evidence more readily suggests that local people self-organise, which results into lower crime rates, solidarity and altruism (Webb, 2007). Therefore, capacities emphasise that local people are the principal source of experiences and creativity that key decision-makers and people working within the realm of DRR must learn from (Oliver-Smith, 1994; Maskery, 1994). It is therefore fitting to harness the insights and participation of these 'first-responders' to understand the actual and potential risk and design measures and tools to reduce risks (Twigg, 2015; Gaillard & Mercer, 2013; Gaillard et al., 2019).

Disasters and disaster risk (DR), therefore, are a function that comprises a hazard (H) with physical mechanisms (magnitude, frequency, speed and spatial extent) or process which may cause potential harm. It also touches on vulnerability (V), that encompass social processes that leads to chronic marginalisation of people. Capacities (C), on the other hand, serves as endogenous protective and coping mechanisms and includes the ability to claim, access and use such resources (Wisner et al., 2011). The consensus in the literature suggests that DRR measures must (1) account the dual nature of disaster (event and process), and (2) how these fundamental concepts (i.e. hazard, vulnerability, capacities) interact and affect people in varying scales (i.e. individual, household, community-at-large). (Hewitt, 1983; Wisner et al., 2003; Bankoff, 2011; Gaillard & Mercer, 2013). The section below describes DRR measures or initiatives in greater details.

This section underscores what DRR is and its three commonly used measures: disaster prevention, mitigation and preparedness. In line with the scope and intentions of this research project, Twigg's (2015) definition appeals to be broader and conclusive. He defines DRR as "the development and application of policies, strategies and practices to reduce vulnerabilities and disaster risks throughout society" (p.6). For Twigg, DRR aims to reduce vulnerabilities and create access, especially for those

who are under the radar and marginalised. Gaillard & Mercer (2013) posit an integration of knowledge and actions from outsider actors (e.g. government, scientists, NGOs) and insider actors (e.g. marginalised groups, local people) to meet the intentions of DRR. However, four major gaps persistently plague DRR measures and processes; these are, (1) distrust between stakeholders, (2) low priority to DRR due to limited resources, (3), absence of space for dialogue and (4) participation fatigue (Gaillard & Mercer, 2013). These gaps therefore serve as evidence that the application of DRR measures and processes are far more complicated in practice.

To define DRR measures involves an arduous task due to technicalities and debates around key concepts. This study adapts Cuny's (1994) definitions (See Table 2). It may be observed through the examples that these concepts overlap, however the context or rationale on how these measures are applied provides a clearer distinction.

Table 2. Definition and examples of DRR measures (adapted from Cuny, 1994)

DRR measure	Definition	Examples
Disaster prevention	Hazard-focused measures that aim to eliminate or drastically reduce its direct effects (p. 204)	• Construction of dams or dikes to prevent flooding • Tsunami embankment
Disaster mitigation	Measures that aim to minimise the disruptive effects of hazards and address vulnerabilities (e.g. political, economic). These measures, therefore, are embedded in development activities.	• Hazard and risk mapping • Strengthening the buildings (hurricane / earthquake resistant buildings) • Planting hazard-resistant crops • Changing the crop planting cycle • Economic diversification • Land-use control • Livelihood or personal insurance • Mangrove conservation / rehabilitation (as a natural barrier for sea-level rise and protection of marine ecosystem) • Zoning and building regulations • Public education • Housing improvement programs (building techniques), • Land swaps or relocation of people from vulnerable to suitable sites, • Flood embankments • Structural inspection or evaluation of buildings and houses. • Modification or replacement of buildings • Community savings or loan programs • Establishment of food banks

Disaster preparedness	Measures that focus on plans and actions that aim minimise loss of lives and assets in response to an immediate threat. These measures provide structure for both emergency and post-disaster plans.	• Warning and evacuation plans, • Stockpiling of supplies or relief goods • Developing emergency plans (e.g. establishing emergency command, control and communications systems) • Improving infrastructure to support or facilitate emergency services • Training in search and rescue and first aid • Developing disaster assessment plans • Establishing relief and reconstruction standards and policies • Developing standby plans for economic assistance to victims • Developing crop salvage and marketing plans for small farmers • Adopting legislation defining emergency powers • Establishing prior inter-governmental and or multilateral agreements for disaster assistance • Zoning and building regulations • Risk mapping • Contingency planning

2.2. Games, simulations, and game design frameworks

Games offer an extension of realities with specific goals and objectives in an artificial world (Pagulayan et al., 2003; Reese, 2009; Huang & Johnson; 2009). In the world of gaming, there are games designed purely for entertainment, learning or a combination of both. This research project focuses on what Clark Abt (1970) calls "serious games". His book entitled "Serious Games" accounts one of the earliest definitions and comprehensive review of serious games. The literature suggests that the contemporary definition refers to serious games as "computerised games" designed not for entertainment, but rather for training or education. This definition limits the scope on other typologies of serious games (Djaouti et al., 2011). This study explores both digital and analogue disaster-themed serious games, utilising both Abt's (1970) and Aldrich & DiPietro's (2009) take of serious games. Abt (1970) defines serious games as games designed to "look into" and simulate real-world topics (e.g. physical and social science, war, government planning). He argues that although these games are not primarily designed for entertainment, the games can still be fun and entertaining. A more succinct definition by Aldrich & DiPietro (2009) refers to “a type of sim (simulation) that increases awareness of a real-world topics, and that can be used both for entertainment and in learning programs” (p.1347).

The steady rise of serious games merits a recognition of its benefits. Abt (1970) underlines the following benefits of serious game simulations worthy of mention. First, serious games allow players to step into a role and look into real-world topics (e.g. wars, disasters, politics). For example, some serious games target children and aims to simulate a volcanic eruption or tsunami. The game mechanics allow the players to play key decision-making roles of government officials and enact large-scale government initiatives. In a real-world setting, this would have been costly to simulate and the management space of DRR would not provide a similar amount of power to children. The game allows children to create solutions, solve problems, analyse, exercise accountability and altruism. This example connects to the second benefit of serious games; they allow players to express understanding and exhibit skills in a way that traditional teaching methods or assessments (e.g. exams) could not capture. The third benefit is that serious games can cater to a diverse set of audience who takes different roles in society

Lastly, the fourth benefit centres around the mechanics of the game. Games often create a space for dialogue on a scale that allows players to reflect on their strategies, processes and decisions. Through this reflection, confrontations and conflicts can be kept at a minimum. A recent review of 45 disaster-themed serious games by Solinska-Nowak et al. (2018) and 34 peer-reviewed journals on the use of serious games in education by Tsekleves et al. (2016) echo the benefits mentioned above. Overall, these benefits serve as evidence of the original intentions of serious games that designers and academia must account for when designing a game. Furthermore, although games bend realities, Abt (1970) argues that "the abstract representation of real-life in-game form does not render the game any less capable of teaching true knowledge" (p. 12).

In general, these games provide significant learning opportunities only if designed effectively (Winn, 2009). However, to design a good game is a difficult task (Pagulayan et al., 2003; Winn, 2009; Dicheva et al., 2015). Games designed for learning need to balance learning outcomes and the 'fun factor' in an iterative and occasionally chaotic process of game design (Winn, 2009; Dicheva et al., 2015). Furthermore, the game designer must understand the interaction of a formal game system that creates a game experience (Fullerton et al., 2004). Therefore, specific approaches or methodologies must be explored to harmonise diverging perspectives & ultimately achieve the goals of the game.

A framework assists in organising a broad range of questions, facts and processes (Wisner et al.,2011). In game development and studies, a game design framework allows diverse backgrounds or viewpoints to achieve a systematic coherence for different parts of a game to relate from one another (Hunicke et al., 2004). Furthermore, a game design framework provides a formal structure that allows game designers and researchers to qualitatively and quantitatively deconstruct and analyse a broad range of games (Hunicke et al., 2004; Walk et al., 2017).

In this study, a framework provides an opportunity to analyse where and how the world of DRR interact with the game world. The list below is among the various frameworks which speak a common

language of the iterative processes of game design and the multiple lens and layers that one can exhaust in constructing or deconstructing a game (See Table 3):

Table 3. Game design frameworks

Author	Title	Game elements
Hunicke, LeBlanc & Zubek, 2004)	MDA Framework	Mechanics, dynamics and aesthetics
Schell, 2008	Elemental Tetrad	Aesthetics, story, technology & mechanics
Winn, 2009	DPE (Design, Play & Experience) Framework for serious games	Learning, storyline, gameplay, user-experience, technology
Walk, Görlich & Barrett, 2017	DDE (Design, Dynamics, Experience) Framework	Design, dynamics, experience
Harteveld, 2010	Triadic Game Design	Play, meaning, reality

The MDA framework was created as a formal game design methodology to assist game developers, scholars & researchers in addressing gaps in "game development, game criticism, and technical game research" (Hunicke et al., 2004). The framework has become one of the most well-cited and widely accepted formal approach in game design and academic curricula. (Walk et al., 2017). Figure 1 illustrates the components of MDA framework. Mechanics are the rules or attributes of the game (e.g. actions, behaviour, control mechanism) that the designer has full control on and defines what the players can do or access in game world. The player's input to these rules forms the dynamics (system), or the run-time behaviour of the game (e.g. competition, bluffing) which is needed to achieve the desired game objectives and desired emotional response or aesthetics (e.g., drama, make-believe, pleasure, fellowship, self-discovery) of a game (Hunicke et al., 2004).

However, more than a decade after its release, a number of game designers released their critics about the framework. The section below highlights challenges in applying the MDA framework (Walk et al., 2017; Winn, 2009):

- It provides more emphasis on the game mechanics or 'functionality' of a game, rather than the 'experience' of a game. Thus, the framework neglects other aspects of game design (e.g. storytelling, narrative, user-experience, technology).
- It focuses more on games designed for entertainment purposes. Hence, it is not suitable for all types of games, like serious games which are gamified content and designed with a unique set of challenges and purpose.

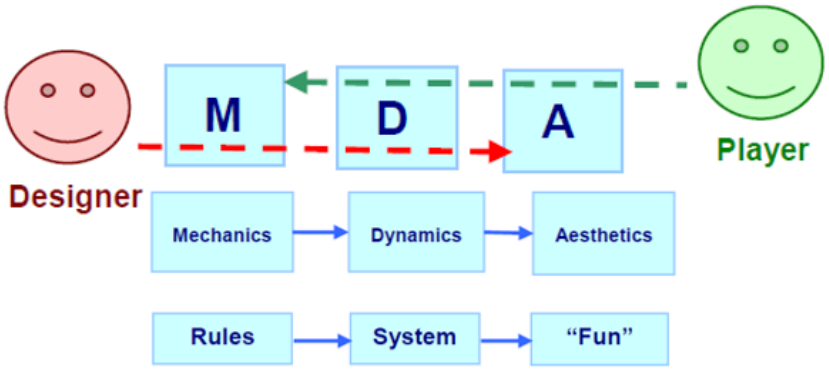


Figure 1. Components of MDA framework adapted from Hunicke et al. (2004)

The game design frameworks such as the DDE (Design, Dynamics, Experience) by Walk et al. (2017), the DPE (Design, Play, Experience) by Winn (2009) and Triadic Game Design (Play, Meaning, Reality) by Harteveld, (2011) were released to address some of these limitations and expand the scope of MDA framework. The last two frameworks were mainly designed for serious games. In line with the scope and layers of serious games that the study aims to analyse, DPE by Winn (2008) provides a comprehensive structure and definition of the game layers that a designer or researcher may choose to explore and investigate.

The DPE framework, according to Winn (2009), expands the widely used and accepted MDA framework. DPE (See Figure 2) primarily aims to design & analyse four game layers of a serious game; it includes; learning, storytelling, gameplay & user experience. Table 4 details the scope and definition of each game layer.

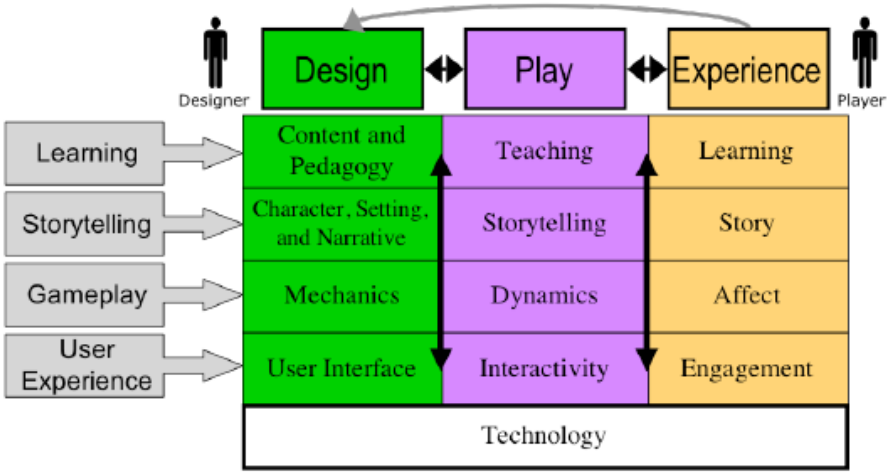


Figure 2. DPE Framework adapted from Winn (2009)

Winn (2009) highlights that the vertical arrows signify how the different game layers interact in gameplay. Therefore, he suggests that the design and analysis be ascertained starting from the top-most layer of the framework. In the process of game design or analysis, he emphasises that the learning layer is the most essential aspect of a serious game but is also the least malleable. The storytelling is intricately weaved into the learning layer and should be addressed next. The gameplay and user experience are considered the most malleable and must coincide with the desired learning and storytelling. Lastly, technology may enable or limit the design of a serious game since the resources needed to implement the technology may significantly affect the overall design process. The next section discusses how the researcher utilised the DPE framework as an overall structure to draw empirical findings.

Table 4. Layers and subcomponents of DPE Framework (adapted from Winn, 2009)

DPE layer	Main component	Subcomponents	Scope & Definition
Learning	Design	Content & pedagogy	Defined by the designer and must be ascertained on the earliest stages of game design.
	Play	Teaching	A result when the content and pedagogy confront the player.
	Experience	Learning	The overall experience of the player with the game.
Storytelling	Design	Character, setting & narrative	Defined by the designer and serves as a primary design tool.
	Play	Storytelling	A combination of the designer's story with the interactions and choices the player makes.
	Experience	Story	Player's story or experience(s) of the game
Gameplay	Design	Mechanics	Rules that define the operation of the game world, this includes; what a player can do, challenges the player will face & the player's goals.
	Play	Dynamics	The resulting behaviour when the rules are incorporated over time with the player's interaction
	Experience	Affect	Emotions or desires defined by the designer
User experience	Design	User interface	Everything the player sees, hears, and interacts. It therefore serves as a vehicle to realize the desired serious outcomes.

	Play	Interactivity	How the interaction of gameplay, storytelling, and learning experience happens in gameplay.
	Experience	Engagement	The ultimate experience the designer aims to achieve for the player.
Technology	Design	Technology	Where the designer builds the whole game. The technology may enable or limit the user experience (e.g. boardgame, cards, video game, puzzles)

3. Research Methodology

3.1. Overall approach

The study primarily enquires how ten disaster serious games frame six fundamental concepts that shape disaster and DRR measures. The researcher, therefore, examined game artefacts (e.g. game manual, cards, worksheets, game notes) to understand and map patterns of claims or reality (Hoggart et al., 2002). In this regard, the researcher takes a constructivist stance. In constructivism, the researcher acknowledges that there are multiple meanings or realities about a specific context. Also, a constructivist approach recognises that the researcher's background (e.g. personal, cultural and social) shapes the interpretation of these realities (Creswell, 2007). In this study, the researcher asserts that the empirical findings of the study only represent one of the many interpretations that can be inferred to understand the realities of disaster and DRR in game world. Thus, in the succeeding sections, game world only refers to the realities portrayed by these ten disaster serious games.

3.2. Methodological framework

In this study, the researcher utilised content analysis as an overall methodological framework to examine disaster serious games. Leedy & Ormrod (2015, p. 275) define content analysis as "a detailed and systematic examination of the contents of a particular body of material for the purpose of identifying patterns, themes, or biases". The authors' highlight that, typically, the content analysis examines forms of human communications or a social artefact (e.g. novels, videotapes, personal journals). The analysis requires the raw data or content to be "coded" to address specific research questions. In this study, the

researcher refers to game artefacts (data) as the content. The game artefact is a combination of written texts and images from the ten disaster serious games. Furthermore, the researcher utilised Wisner et al.'s (2011) disaster risk mnemonic and Winn's (2009) DPE framework to systematically organise data from each game. Figure 3 shows the stage model of qualitative content analysis that the researcher applied to draw empirical findings.

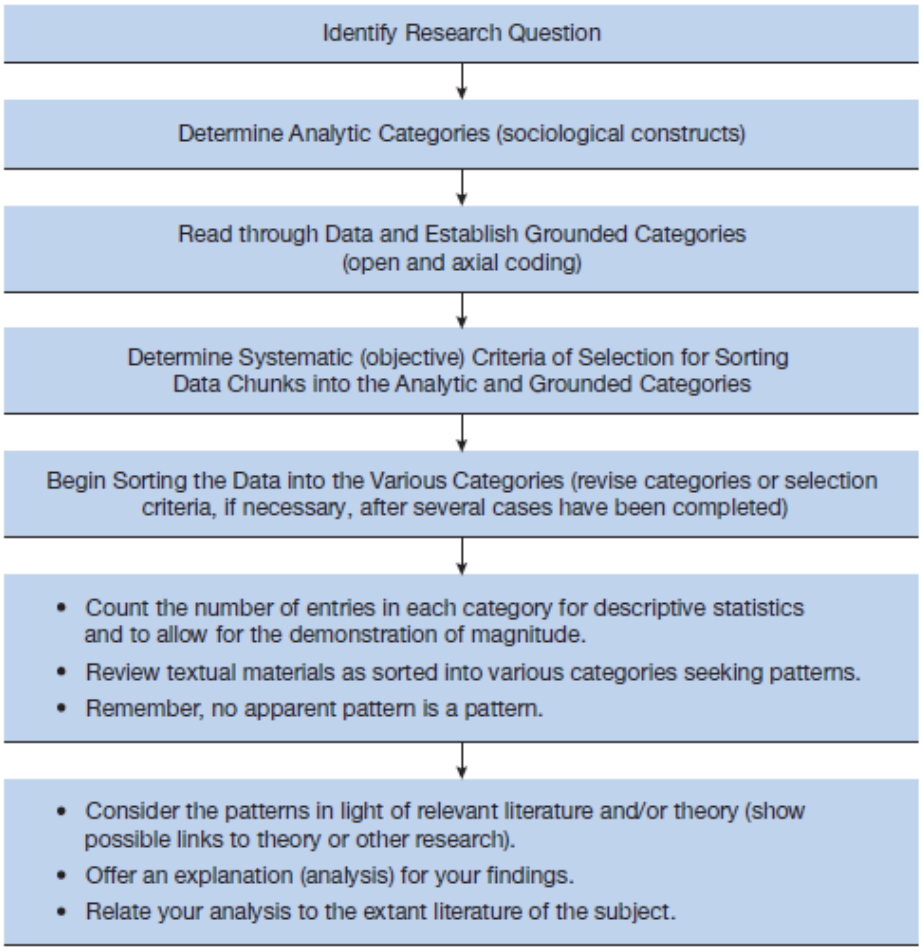


Figure 3. Stage Model of Qualitative Content Analysis (adapted from Lune & Berg, 2017)

3.3. Data Collection

First, it is important to highlight that the researcher could not conduct any field work. As a result, the researcher had to resort to desktop review and scout for serious games that were easily accessible in campus, game stores, Internet search engines (i.e. Google, Youtube) and other online databases (i.e. Games4Sustainability).

Video games were more accessible compared to analog games (i.e. board games, card games and puzzles). Therefore, the researcher scouted for analog serious games on campus and other game stores to start identification of serious games. On campus, the researcher came across the analog games *Riskland*, *Iggy's DRR game* and *Impact*; along with the video games *EarthGirl Volcano, EarthGirl 2*, *Sai Fah! The Flood Fighter*. All of these games were either used in lectures or disaster prevention and mitigation seminars held at the School of Environment. Also, recent studies of Gampell and Gaillard (2016) and Solinska-Nowak et al. (2018) provided an appendix of disaster serious games which made it easier to expand the list of games to include in the study. Lastly, the researcher accessed an online game database Games4Sustainability which features a Gamepedia where different serious games aligned to a particular sustainable development goal can be accessed for free.

The researcher created a list of inclusion and exclusion criteria (See Table 5) to identify which games to include in the study; some of these criteria were adapted from the study of Gampell and Gaillard (2016). In most studies, the researchers would exclude serious games created by amateurs. The researcher, being a co-author of disaster serious games herself, argues that all games have merit and must be treated of equal importance. The credibility and value of disaster serious games must not be attached to the organisations that produced them; instead, a game's value must account for the accessibility and the realities it represents to the target audience. It is for this reason that this study also included games which may not have been used in community awareness activities but are highly accessible online.

Table 5. Disaster serious games inclusion and exclusion criteria

Inclusion	Exclusion
• The serious game must have been used in either of the following: - Awareness activities (school, community, government activities or online). - Previous serious game studies • The serious game must cover at least one of the following DRR concept: - Hazard	• Commercially produced disaster serious games • Climate change • Technological disaster • War • Food security

- Vulnerability - Capacities - DRR initiatives (disaster prevention, mitigation and preparedness) • Natural hazard • Tagalog and English language • Non-commercial analog games (i.e. board games, card games, puzzles) • Non-commercial video games with Windows, IOS and Android operating systems	• Zombies • Post-apocalyptic

Finally, the researcher considered two other aspects in deciding the games to analyse: (1) the number of game layers and (2) DRR concepts for each game. As a result, the researcher arrived with a list of ten disaster serious games thoroughly discussed on the next chapter.

The disaster risk mnemonic of Wisner et al. (2011) and DPE framework of Winn (2009) provided a robust structure to systematically organise the data for analysis. The data collection of the ten disaster serious games began through gameplay. After each gameplay, the researcher organised the data by learning goals and DRR concept (e.g. hazard, capacities) following Wisner et al.'s (2011) mnemonic. In addition, the researcher organised her gameplay notes per mechanics, dynamics and affect to capture how the concepts unfold through play. Finally, the researcher labelled the game layers where each concept was most visible.

3.4. Types of data/informants

The study identifies three categories of game artefacts. First are the written texts and images from the game manuals, cards, maps, worksheets and, in the case of video games all texts and images that flashed on the screen relevant to the study. Second are game overviews (written texts) of some games (i.e. *Before the Storm*, *EarthGirl Volcano*, *Sai Fah! The Flood Fighter*) found on the internet. Third are written texts from the researcher's game notes after playing each game. These notes became a source for understanding the gameplay and user experience layer of each game. Table 6 shows the frequency that the researcher played each game. The more complex the game mechanics and storytelling layer (e.g. challenges), the higher the frequency of playing the game. However, not all games have a storytelling layer like the games Natural Disaster, and Word Hunt. Therefore, data from these games were easily collected.

Table 6. The researcher's frequency of gameplay

Game	Game type	Frequency (no. of times played)
Earth Girl Volcano	Video Game	4
Earth Girl 2	Video Game	4
Sai Fah! The Flood Fighter	Video Game	3
Riskland	Boardgame	2
Impact	Boardgame	3
IGGY's DRR	Card game	2
Before the Storm	Card game	2
Tectonic Plate	Jigsaw Puzzle	1
Natural Disaster	Crossword Puzzle	1
Word Hunt	Crossword Puzzle	1

3.5. Approach to data analysis

The interpretative approach provides means to discover the practical meanings from a collection of texts (e.g. written words, image, field notes) and actions. Furthermore, the approach allows interpretation of data in line with a theoretical orientation chosen by the researcher (Lune & Berg, 2017). To ascertain patterns of meaning, first, the researcher identified analytical categories from DRR and serious games' studies in line with the research questions. The researcher then, identified Wisner et al.'s (2011) disaster risk mnemonic and Winn's (2009) serious game design framework to categorise and organise all game artefacts. After this, the researcher conducted the following steps to uncover both manifest (explicit) and latent (implicit) meanings from the game artefacts (See Figure 4). The process started in gameplay, where the researcher immersed herself in different game layers or world built by the game designer. The researcher was able to draft her game notes after each gameplay. These notes became a source for understanding the gameplay and user experience layer of each game. The researcher then organised all data from the game artefacts as per Wisner et al.'s (2011) disaster risk mnemonic and Winn's (2009) DPE framework. Both the mnemonic and framework provided a structure to determine social constructs about disasters and DRR. The researcher eventually open-coded fundamental concepts. Finally, after successive axial coding of themes and images for each fundamental concept, the study identified 54 themes. Overall, the researcher analysed each theme with an interpretative constructivist approach.

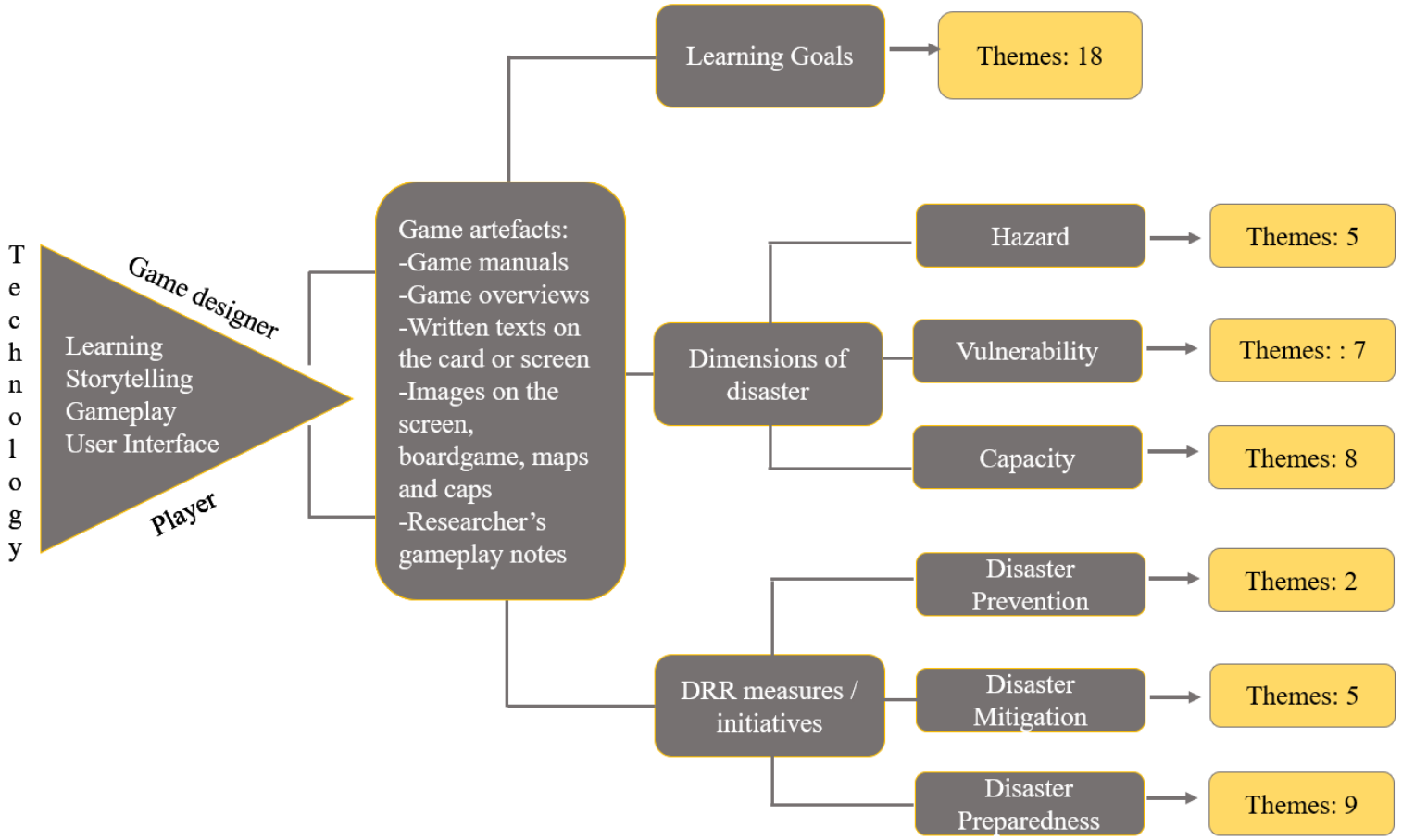


Figure 4. Content analysis of the study

3.6. Positionality and other ethical issues

The world of serious game design consists of a diverse set of individuals or groups (Winn, 2009). The researcher positions herself as part of the DRR and serious game design community. Her background and practical experiences in health, community-based DRR and in co-designing disaster serious games allow her to interpret the realities of game world in a different lens. In analysing a game, she asserts the importance of completing the game experience first, to allow the original game design (i.e. learning, storytelling, gameplay, user-experience) to unfold naturally. Doing so eliminates the bias of analysing each game layer prematurely. Furthermore, she recognises that the assumptions made in the study are not the absolute representation constructed by each game. Instead, she offers a different perspective of "looking into" disaster serious game to address a gap in the literature and ways forward in gamifying disasters and DRR.

4. Disaster and fundamental concepts of DRR in game world

The increase in number, popularity and use of games as a tool in raising awareness for DRR inspired this study (Gampell et al., 2017; Solinska-Nowak et al., 2018). While most studies on disaster-themed serious games focused on analysing the potentials, effectiveness and impact of games as a tool in disaster education (Di Loreto et al, 2012; Gampell et al., 2017; Solinska-Nowak et al., 2018), this study takes a different path. This research focuses on how different types of non-commercial serious games (digital & analog) frame and promote fundamental concepts of DRR. These concepts—hazard, vulnerability & capacity—are used to inform DRR measures (e.g. prevention, mitigation, preparedness) which are embedded and interact with the game elements (e.g. narrative, player experience). This study argues that in order to build evidence and reshape gamification of DRR concepts, we must first step back and analyse how game world represented these concepts in the past years. It is explained that these representations are an extension of the realities and practices it offers to the players. The study also stresses that the hazard alone, does not define the causality and realities of disasters (Wisner et al., 2011; Gaillard & Mercer, 2013).

Table 7 summarises the different DRR concepts that each game represents. These were either overtly or covertly observed in the different game layers. Among the three main concepts of disasters, vulnerability has the least representation compared to hazard and capacity. On the other hand, disaster prevention is the least simulated DRR measure compared to preparedness and mitigation. The subsequent section details how the aforementioned concepts were simulated in each game, using the mnemonic of disaster risk of Wisner el al. (2011) and game layers of the DPE framework on serious games by Winn (2009).

Table 7. Summary of DRR concepts covered by disaster-themed serious games

Game Title	Author/Publisher	Type	Target Player	Hazard	Vulnerability	Capacities	Prevention	Mitigation	Preparedness
Earthgirl Volcano	ART Group at the Earth Observatory of Singapore	Video Game	Children (7-13 y/old)	✓	✓	✓		✓	✓
EarthGirl 2	ART Group at the Earth Observatory of Singapore	Video Game	Children (7-13 y/old)	✓	✓	✓		✓	✓
Sai Fah! The Flood Fighter	Opendream, The Department of Non-formal Education at the Ministry of Education in Thailand, UNESCO BANGKOK	Video Game	Children	✓	✓	✓	✓		✓
Riskland	Inter-agency Secretariat of the International Strategy for Disaster Reduction (UNISDR) for Latin American, and the United Nations Children's Fund (UNICEF-TARCO)	Board game	The vulnerable community of Latin America and the Caribbean, kids aged 8–12	✓	✓	✓		✓	✓
Impact	Idea Couture	Board Game	Government officials, educators, students aged 16+	✓		✓	✓	✓	✓
Iggy's DRR Game	UNISDR Unicef IFCRC	Card Game	Children and adults (all ages)	✓		✓		✓	✓

Before the Storm	Red Cross/Red Crescent Climate Centre	Card Game	Community members/donors/disaster managers/volunteers/branch officers	✓		✓		✓	✓
Tectonic Jigsaw Puzzle	University of Waikato (2017)	Jigsaw Puzzle	Students	✓					
Word Hunt	Center for Disaster Preparedness (2019)	Crossword puzzle	Not specified	✓		✓		✓	
Natural Disaster Crossword Puzzle	WorldMint LLC (2016)	Crossword puzzle	Not Specified	✓					

4.1. Learning goals of disaster serious games

4.1.1. Hazard-focused learning goals

The learning goals serve as the basis for designing the overall game content and player experience. Winn (2009) argues that designers must first identify the learning goals since it is the most essential and least malleable component of a serious game. This section narrates the desired learning goals of 10 disaster-themed serious games explicitly highlighted in-game manuals or overviews. Table 8 shows the learning goals each game possesses and desires to achieve. These goals are most visible at the learning and story levels (i.e. game manuals, overviews, written texts in cards or worksheets) and gameplay (i.e. mechanics). Furthermore, the table shows the ability of games to feature a combination of learning goals or realities regardless of the game typology. The subsequent parts of this section discuss the results in greater detail.

The results of the analysis show that most games aim to raise awareness on (1) physical characteristics of hazards, (2) possible hazard impacts, and (3) promote hazard specific DRR initiatives. This means at the earliest phase of game design, most games were predisposed to form realities and causalities of disasters based on hazard paradigm. As a result, players associate the occurrence of disasters mainly because of hazards. On one hand, this kind of framing reinforces specific knowledge and practices that people enact in facing hazards. Subsequently, it leads the players to think that effective risk reduction mainly involves understanding the physical mechanisms and probable impact of these hazards.

To highlight a few examples, *Before the Storm* is a card game that familiarise players with the importance of understanding weather-related forecasts. The game overview and written texts on the cards explicitly reinforces alignment of the player's decision with the storm scenario. Similarly, *Impact* is a foresight card game that encourages players to take roles (e.g. scientists, human resource specialist, ecosystem architect) focused on contributing to the society by addressing extreme events (e.g. emergence of a superbug, increase of weather-related events). All of the ten disaster-themed serious games follow this type of storyline.

In an attempt to investigate covert learnings and representation of disasters and DRR, the researcher analysed the gameplay layer. The results reveal how gameplay (i.e. mechanics) can skew the representation of a concept during play. For example, one of the aims of *Riskland* is to reward or penalise players for the DRR measures they take. One of the surprise cards (See Figure 5) depicts a scenario wherein the player must question the mayor's office decision for allowing the school to be rebuilt in a flood zone area. In the given scenario, the act of claiming one's involvement (capacity) in decision making processes must have been rewarded. Instead, the player who picks the surprise card must go 1 space back from the hazard map. Similarly, *EarthGirl2* depicts panicking of local people to go to a safe location after the warning signals was activated (See Figure

6). However, research shows that local people are usual aware and have knowledge and skills to reduce risks associated with natural hazards (Wisner et al., 2003; Wisner et al., 2011; Twigg, 2015). Thus, they can organise themselves effectively rather than in panic, and execute altruism rather than helplessness and selfishness (Quarantille & Dynes, 1972; Oliver-Smith, 1994; Maskrey, 1994).

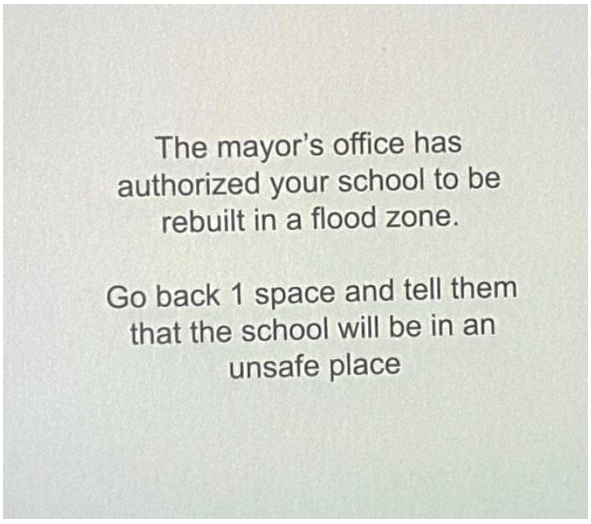


Figure 5. DRR participation scenario in Riskland

Finally, this section underscores how games serve as source or vehicle of realities and causalities of disasters. The results of this section highlight that all ten games simulate DRR as a priority. However, the overall game narratives reflect a dominant view (hazard paradigm) that links disasters and DRR initiatives with hazards. Furthermore, the examples in this section also highlight that disasters in-games are dealt with at varying scales (i.e. individual, household, community-at-large). Further, gameplay and mechanics can potentially skew simulation of the concepts attached to the desired learning goals. Therefore, the results reiterate the challenge for game designers to recalibrate game design strategies in order to effectively harmonise DRR concepts and game elements.

Figure 6. Panic of local people in EarthGirl2

Table 8. Learning goals of disaster-themed serious games

No.	Game Title & Type	Hazard(s)	Game Layers: Learning, Storytelling and Gameplay						
			Raise awareness on physical characteristics of hazards	Raise awareness on possible impact of hazards	Promote DRR initiatives	Reinforce knowledge & practices in facing hazards	Promote solidarity to survive / mitigate effects of disaster/hazards	Highlight unsafe conditions that contribute to disasters	Highlight bad DRR practices
1	Earth Girl Volcano Type: Video Game	Volcanic Eruption	✓	✓	✓	✓	✓	✓	
2	Earth Girl 2 Type: Video Game	Tsunami	✓	✓	✓	✓	✓	✓	
3	Sai Fah! The Flood Fighter Type: Video Game	Flood and landslide	✓	✓	✓	✓	✓	✓	✓
4	Riskland Type: Boardgame	Earthquake Landslide Cyclone/Typhoon Flood Fire			✓	✓	✓	✓	✓
5	Impact Type: Boardgame	Sea-level Rise Increase of weather-related events Deadly Super Bug		✓	✓		✓		
6	IGGY's DRR Type: Card game	Drought Heatwave Cyclone Rising sea-level Fire	✓	✓	✓	✓	✓		

		Flo Earthquake Tsunami							
7	Before the Storm Type: Card Game	Storm/ Typhoon	✓	✓	✓		✓	✓	
8	Tectonic Plate University of Waikato Type: Jigsaw Puzzle	Earthquake	✓	✓					
9	Natural Disaster Type: Crossword Puzzle	Multi-hazard	✓	✓					
10	Word Hunt Type: Crossword puzzle	Covid-19	✓	✓	✓		✓		

4.1.2. Integrative disaster risk reduction in game world

Gameplay according to Winn (2009) is divided into three layers: mechanics, dynamics and affect. All of these layers are connected to each game's learning goals. The mechanics define the rules of operation. This includes what the player can do (e.g. choose a map, take turns, skip a player), assets that the players can exhaust (e.g. dice, cards, power buttons, game clues) and the different challenges the players will face. Dynamics happen when the player interacts with the mechanics of the game (Winn, 2009). The result or experience induce affect (e.g. discovery, altruism, competition, power), which Heeter et al. (2003) describes as different forms of fun.

Table 9 shows the themes that emerged from each game typology based on the game storyline, mechanics and the researcher's gameplay experience (dynamics and affect). The results reveal that games can simulate an integrative process of DRR. This means that significant risk reduction in-game are met through:

(1) trust between stakeholders (in this case players and game characters),

(2) opportunities for dialogue,

(3) DRR is portrayed as a priority, and

(4) both top-down and bottom-up DRR approaches (Gaillard & Mercer, 2013).

The analysis also reveals that not all games can simulate the aspects mentioned above in full circle, and the simulation varies in all games. For example, *EarthGirl Volcano* and *EarthGirl 2* bring a player to the supermarket for the game characters to share their living conditions, experiences in hazards and their opinion in reducing risks (See Figure 7). The game mechanics assume that the game character's (local people) opinion will influence the player's decisions. After the consultation, the game mechanics put the player in a powerful position with complete access to resources (e.g. budget). This kind of game mechanics promotes creativity and problem-solving skills and simulates top-down and bottom-up approaches in DRR (See Table 9). Similarly, *Sai Fah! The Flood Fighter* showcases a top-down approach because the game mechanics do not allow the player to decide how Sai Fah will face specific challenges. Instead, the designer has predetermined a set of tasks that the player must follow to accomplish each game level. Overall, the gameplay of video games offers a real-time and highly visual simulation of the positive and negative impact of one's decisions in a scale that can be easily understood and would have been costly if simulated in the real world (Abt, 1970).

Among the games, *Riskland* encompasses all the aspects of an integrated DRR process. The game mechanics allow dialogue between players and provide opportunities for facilitators to co-author game scenarios by providing blank cards. In terms of storyline, the game rewards surprise cards feature an example of stakeholders coming together to prioritise DRR (See Figure 8). For example, some surprise cards depict a situation wherein trust and access to resources are given to the players (children or adults) to organise hazard mapping and other DRR initiatives. Most game scenarios also portray that

the player and local villagers who are often excluded in decision-making processes have the capacity (knowledge and skills) to shape DRR initiatives.

Figure 7. Local people's consultation in EarthGirl Volcano and EarthGirl2

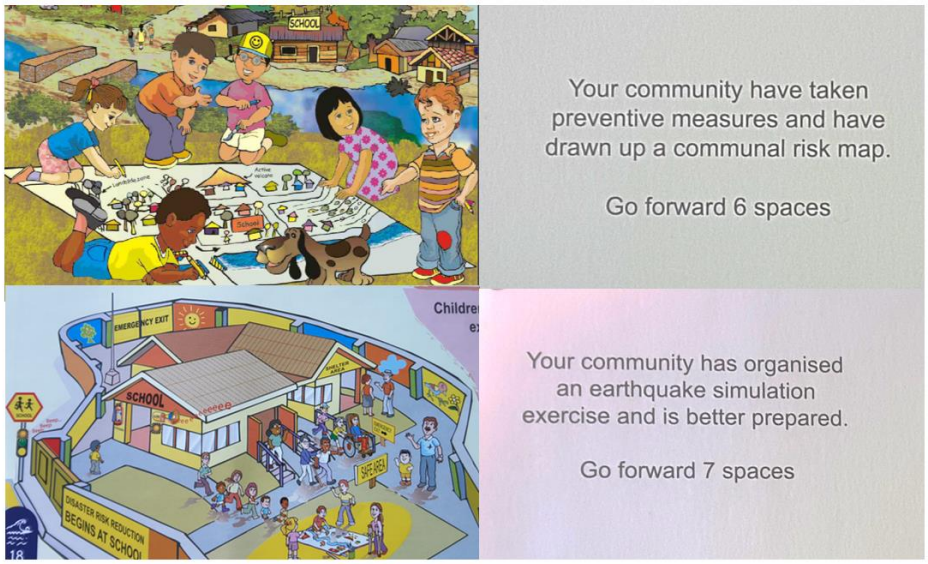


Figure 8. DRR as a priority in Riskland

Table 9. Integrated DRR in game world

Game Title & Type	Hazard(s)	Game Layer: Storytelling and Gameplay (Mechanics and Dynamics)					
		B1: Promotes dialogue between players	B2: Promote dialogue with game characters	B4: Reward good practices in DRR	B5: Demerit bad practices in DRR	B6: Simulate top-down DRR management	B7: Simulate bottom up DRR management
Earth Girl Volcano Type: Video Game	Volcanic Eruption		✓	✓	✓	✓	
Earth Girl 2 Type: Video Game	Tsunami		✓	✓	✓	✓	
Sai Fah! The Flood Fighter Type: Video Game	Flood and landslide		✓	✓	✓	✓	✓
Riskland Type: Boardgame	Earthquake Landslide Cyclone/Typhoon Flood Fire	✓		✓	✓		✓
Impact Type: Boardgame	Sea-level Rise Increase of weather-related events Deadly Super Bug	✓		✓		✓	

IGGY's DRR Type: Card game	Drought Heatwave Cyclone Rising sea-level Fire Flo Earthquake Tsunami	✓					✓
Before the Storm Type: Card Game	Storm/ Typhoon	✓				✓	✓
Tectonic Plate University of Waikato Type: Jigsaw Puzzle	Earthquake	✓					

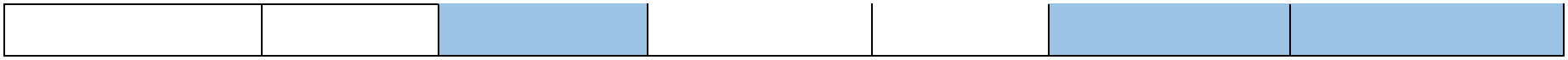
In terms of affect (fun) layer, Table 10 shows that most games promote altruism. This means that although most games promote competition between players, the overall game experience immerses players in roles and challenges that aim to help others (Heeter et al., 2003), in this case, save lives and assets from hazards. The competition must be viewed as a trigger to creativity and problem solving, which induces the player's game experience. For example, players of Iggy's DRR must compete by singing, dancing, drawing or acting to describe a DRR concept (e.g. ensure availability of water for humans and animals). Similarly, but on a different scale of difficulty, players of Impact must reach a specific number of influence cubes to solve an extreme event (e.g. superbug) that concerns the society. The competition in Impact can trigger disagreements between players as they rally to compete for the influence cubes. In this regard, the facilitator plays a vital role to make sure that players have fun and exhibit positive attitudes (e.g. competition, fellowship, altruism) while playing the game.

Overall, this section reiterates how interrelated the game layers are to each other Regardless of the game typology, the storytelling and gameplay layer allows the learning goals of serious games to expand. Lastly, by dissecting these layers, one can investigate disasters and DRR representations that are not visible on game manuals or overviews.

Table 10. Underlying representations of DRR in game world

Game Title & Type	Hazard(s)	Game Layer: Affect				
		Compete with players	Exercise power in shaping DRR initiatives	Promote creativity	Enhance problem solving skills	Promote altruism
Earth Girl Volcano Type: Video Game	Volcanic Eruption		✓	✓	✓	✓
Earth Girl 2 Type: Video Game	Tsunami		✓	✓	✓	✓
Sai Fah! The Flood Fighter Type: Video Game	Flood and landslide				✓	✓
Riskland Type: Boardgame	Earthquake Landslide Cyclone/Typhoon Flood Fire	✓		✓		✓

Impact Type: Boardgame	Sea-level Rise Increase of weather-related events Deadly Super Bug	✓	✓	✓	✓	✓
IGGY's DRR Type: Card game	Drought Heatwave Cyclone Rising sea-level Fire Flo Earthquake Tsunami	✓		✓	✓	✓
Before the Storm Type: Card Game	Storm/ Typhoon	✓		✓	✓	✓
Tectonic Plate University of Waikato Type: Jigsaw Puzzle	Earthquake				✓	
Natural Diaster Type: Crossword Puzzle	Multi-hazard				✓	
Word Hunt Type: Crossword puzzle	Covid-19	✓			✓	✓



4.2. Hazard, vulnerability and capacity in game-world

4.2.1. Hazard as a natural and disruptive phenomenon

Table 11 summarises how disaster-themed serious games frame the concept of hazard. These representations are most visible in the storytelling (i.e. narrative), user interface and gameplay layers of all games. The results of the analysis reveal that games frame hazard as a natural phenomenon with distinct physical characteristics (e.g. strong wind of a typhoon; big waves of a tsunami; shaking of an earthquake; water & debris from floods) which may affect a social system and may lead to loss of lives, damage to physical structures, environment & livelihood. For example, the video game *Sai Fah! The Flood Fighter* portrays that floodwaters result in the inundation of houses and schools, and separate people from their loved ones. In order to survive, the player character Sai Fah explores different flood preparedness and mitigation measures to help others and reunite with his mother and grandmother. Similarly, the board game *Riskland* takes a player on a multi-hazard map and describes different examples of DRR initiatives to prevent, prepare or mitigate risks for a specific hazard. The same storyline applies to *Earthgirl Volcano*, *EarthGirl 2*, *Impact*, *Iggy's DRR Game* and *Before the Storm*. Therefore, hazard acts as a vehicle to introduce the other dimensions of disaster (i.e. vulnerabilities, capacity) and DRR measures (i.e. prevention, mitigation and preparedness) respectively.

Furthermore, the results reveal that people's contribution to hazards is due to poor housing materials, livelihoods that promote deforestation or ecologically harmful farming techniques. However, these game scenarios only focus on proximate factors of vulnerability at the detriment of root causes (Cannon, 1994). Furthermore, these game scenarios put greater accountability on local people who are, often away from positions of power and have little control over external forces (e.g. political and economic systems) that affect their daily lives (Wisner et al., 2003)

Overall, this section reveals that disaster in games is an event and not a process because most games immerse players in a storyline and gameplay that begins with a hazard scenario within a specific time and space. Furthermore, most of the storyline and content simulate a surface representation of vulnerability. They thus overlook social processes which disproportionately affect people in everyday living conditions and a hazard event. Therefore, the overall framing of games mirrors the hazard paradigm as per Burton et al. (1978) and Kates (1971), who assert that disasters result from people's failure to perceive risk and adjust to extreme natural hazards (Gaillard & Mercer,2013).

Table 11. Hazard in game world

Game Title / Type	Hazard	Game layer	Hazard, a disruptive phenomenon	Hazard, a natural phenomenon	People's contribution to hazards	Hazards measured by technology	Physical characteristics of hazards
Earth Girl Volcano Type: Video Game	Volcanic Eruption	Storytelling	✓	✓			✓
		User Interface	✓	✓			✓
		Gameplay	✓	✓			✓
Earth Girl 2 Type: Video Game	Tsunami	Storytelling	✓	✓			✓
		User Interface	✓	✓			✓
		Gameplay	✓	✓			✓
Sai Fah! The Flood Fighter Type: Video Game	Flood & Landslide	Storytelling	✓	✓			✓
		User Interface	✓	✓			✓
		Gameplay	✓	✓			✓
Riskland Type: Boardgame	Earthquake	Storytelling	✓	✓	✓	✓	✓
		User Interface	✓	✓	✓	✓	✓
		Gameplay					
	Landslide	Storytelling			✓		✓
		User Interface			✓		✓
		Gameplay					

	Tsunami/Tidal wave	Storytelling					✓
		User Interface					✓
		Gameplay					
	Volcanic Eruption & Volcanic Ash	Storytelling					✓
		User Interface					✓
		Gameplay					
	Hurricane/Typhoon	Storytelling	✓				✓
		User Interface	✓				✓
		Gameplay					
	Tornado	Storytelling	✓				✓
		User Interface	✓				✓
		Gameplay					
	Flood	Storytelling	✓	✓	✓		
		User Interface	✓	✓	✓		
		Gameplay					
	El Nino	Storytelling	✓	✓			✓

		User Interface	✓	✓			✓
		Gameplay					
	Fire	Storytelling		✓	✓		✓
		User Interface		✓	✓		✓
		Gameplay					
	Plague	Storytelling		✓	✓		✓
		User Interface		✓	✓		✓
		Gameplay					
	All hazards	Storytelling			✓		
		User Interface			✓		
		Gameplay					
Impact Type: Board Game	Sea-level Rise Increase of weather-related events Deadly Super Bug	Storytelling	✓				
		User Interface	✓				
		Gameplay					
Iggy's DRR Type: Card game	Drought Heat Wave Cyclone	Storytelling	✓				✓
		User Interface	✓				✓

	Fire Flood Earthquake	Gameplay					
	Tsunami	Storytelling		✓			✓
		User Interface		✓			✓
		Gameplay					
Before the Storm Type: Card Game	Storm/ Typhoon	Storytelling	✓	✓		✓	✓
		User Interface	✓	✓		✓	✓
		Gameplay					
Tectonic Plate University of Waikato Type: Jigsaw Puzzle	All hazards	Storytelling		✓			
		User Interface		✓			
		Gameplay					
Natural Disaster Type: Crossword Puzzle	Multi-hazard	Storytelling	✓	✓			✓
		User Interface	✓	✓			✓
		Gameplay					
Word Hunt Type: Crossword puzzle	Covid-19	Storytelling	✓				✓
		User Interface	✓				✓
		Gameplay					

4.2.2. Vulnerability in game world

This section highlights how games depict the concept of vulnerability by describing the themes that emerged through the game layers. Table 12 shows that, among the ten games, only *Earthgirl Volcano*, *EarthGirl 2*, *Sai Fah! The Flood Fighter* and *Riskland* touched on the concept of vulnerability. The analysis revealed that video games are able to articulate vulnerability in all game layers compared to the board game *Riskland,* wherein vulnerability is only described through written content on the cards. Furthermore, video games offer an interactive, 3-dimentional and real time narrative of characters and impact of disasters compared to boardgames wherein players are only confronted to flat images or plain texts.

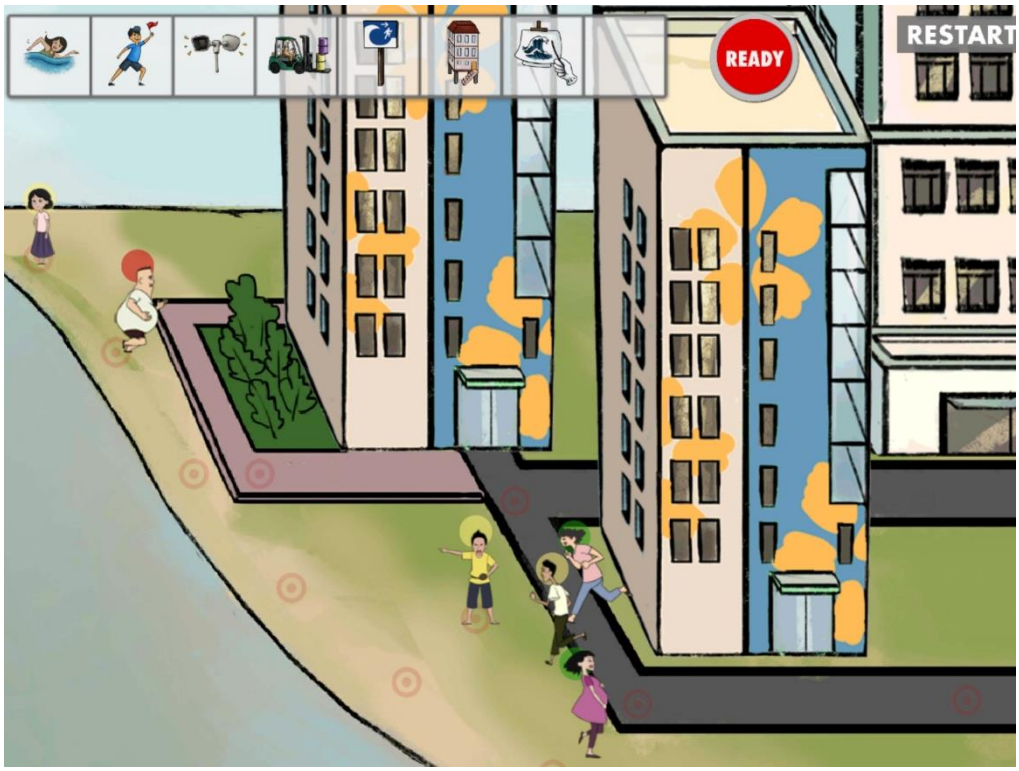


Figure 9. Local people's level of awareness in EarthGirl2

Vulnerability is framed as resulting from (1) low awareness of local people, (2) poor structural materials and design of houses or buildings, and (3) lack or poor mitigation measures. *Earthgirl Volcano* and *EarthGirl 2* highlight that villagers have three levels of awareness on the possible impact of hazards (i.e. volcanic eruption and tsunami) (See Figure 9). Villagers that have poor risk perception are portrayed by characters with red halo, average perception with orange halo and good perception with green halo: only the villagers with green halo will follow the evacuation signs and procedures and go to a safe place. Both

games illustrate low awareness of risk through houses built near the river or volcano, poor structural materials of houses and other buildings (See Figure 10). To reduce risks, the player is put in a position of power who has full access to a budget. Although the dynamics of the games provide an opportunity for the player to check the opinion of the villagers in the market (See Figure 7). The player has the ultimate power to decide which mitigation measures to utilise (e.g. community awareness sessions, instalment of evacuation signs and early warning device or structural reinforcement of buildings) to ensure evacuation of villagers and prevent loss of lives (See Figure 11). Additionally, *Riskland* represents low awareness through scenarios such as failure to check the expiry date of emergency supplies, and reluctance to follow evacuation procedures. Similarly, the main character of *Sai Fah! The Flood Fighter* enters his grandmother's house without the go signal of the rescue team (See Figure 12).

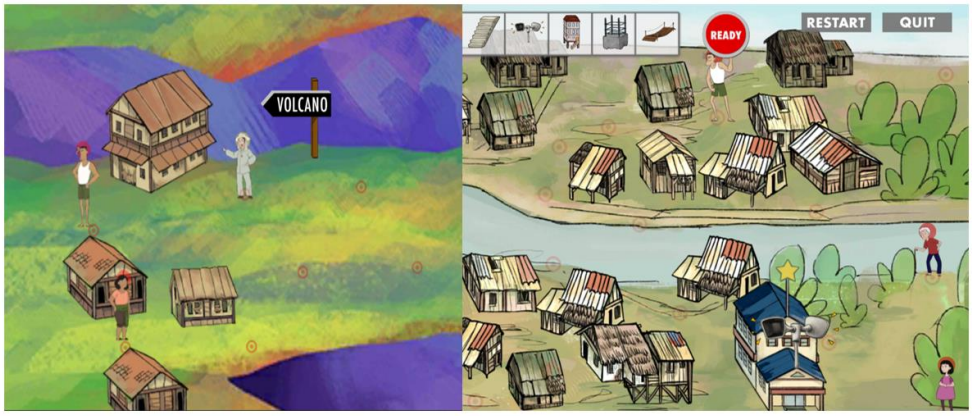


Figure 10. Unsafe conditions in EarthGirl Volcano and EarthGirl2

Figure 11. Player's resources in EarthGirl Volcano and EarthGirl2

Other minor themes that emerged from our analysis are (1) lack or poor local leadership, (2) social inequality, (3) ecologically harmful livelihood practices and (4) traditions (e.g. gossiping or false messages from neighbours). *Earthgirl Volcano* and *EarthGirl 2* highlight the importance of investing in local leadership. They are portrayed by individuals who hand signal the villagers to evacuate to a safe place (See Figure 13). The presence of these individuals expedites evacuation procedures. Hence, the player's failure to invest in local leadership results in slower evacuation procedures or loss of lives. *Riskland* offers a different scenario by holding the mayor accountable for allowing a school to be rebuilt in a flood zone area (See Figure 5). Furthermore, *Riskland* highlights ecologically harmful livelihood practices that cause landslides or flooding. These are grazing livestock in the same area for too long, not practicing intercropping and poor waste management of factories (See Figure 14).

Figure 12. Dialogue between Sai Fah and the rescue team

Overall, the different games emphasise the "conditions generated by human systems" (p.20) that lead to disasters (Cannon, 1994). Most of the games depict characteristics of unsafe living conditions and actions of the villagers (individuals and collectives) as the root causes of vulnerability to hazards. Therefore, the games tend to blame individuals for their own vulnerability. In contrast, the root causes of vulnerabilities, such as the unequal distribution of wealth and resources and associated social and political constraints are not simulated in any of the games.

Figure 13. Local leader's role in EarthGirl Volcano and EarthGirl2

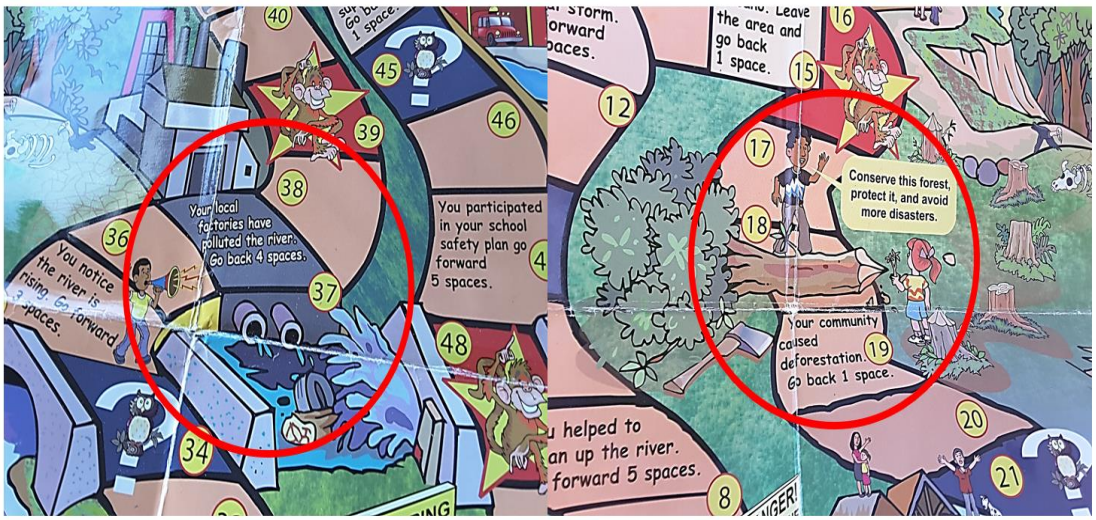


Figure 14. Ecologically harmful livelihood practices in Riskland

Table 12. Vulnerability in game world

Game Title	Type	Hazard	Game layer	Lack of local leadership	Low awareness level of local people	Social structure inequities	Traditions	Poor structural materials and design	Lack or poor mitigation measures	Ecologically harmful livelihood practices
Earthgirl Volcano	Video game	Volcanic eruption	Storytelling	✓	✓			✓	✓	
			User interface	✓	✓	✓		✓	✓	
			Gameplay	✓	✓			✓	✓	
EarthGirl 2	Video game	Tsunami	Storytelling	✓	✓					
			User interface	✓	✓			✓	✓	
			Gameplay	✓	✓			✓	✓	
Sai Fah! The Flood Fighter	Video game	Flood & landslide	Storytelling		✓	✓	✓			
			User interface		✓	✓	✓			
			Gameplay		✓	✓	✓			
Riskland	Boardgame	Earthquake	Storytelling					✓	✓	
			User interface					✓	✓	
			Gameplay							
		Landslide	Storytelling							✓
			User interface							✓
			Gameplay							
		Flood	Storytelling	✓						✓
			User interface	✓						✓
			Gameplay							
		All hazards	Storytelling	✓	✓	✓		✓	✓	
			User interface	✓	✓	✓		✓	✓	
			Gameplay							

4.2.3. Capacities in game world

Table 13 describes capacities as a diverse set of knowledge, skills and resources the player and/or other characters "can claim, access and resort to in dealing with hazards and disasters" (Gaillard et al., 2019, p. 863). A majority of games portray knowledge and practices to face a particular hazard and access an array of resources while others touch on mutual assistance, the ability to design and lead DRR measures and the presence of technical expertise. Furthermore, capacities in games are place based and the player and game characters share a common belief and interest in reducing risk. People within a specific geographic location interact with trust, share resources (i.e. technology, basic needs, social services), or ensure mechanisms are in-place to access needed resources. *EarthGirl Volcano*, *EarthGirl 2* and *Riskland* explicitly feature place-based capacities using maps where the player starts the game mission (See Figure 15). *Sai Fah! The Flood Fighter*, *Iggy DRR* and *Before the Storm*, on the other hand, include capacities through game scenarios.

Figure 15. Capacity as place-based in game world

Knowledge and practices are evident at three levels; individual, household and community. For example, in a community-level *Before the Storm* highlights sandbags as a cost-effective resource to prevent floodwater from reaching houses. At the household level, *Sai Fah! The Flood Fighter* includes a scene when Sai Fah asks for an elderly chief's advice on how to make a sandbag barrier to prevent flood water from entering her house (See Figure 16). *Iggy's DRR* focuses on individual and household knowledge and practices. These include the use of "grey water" for watering crops as a water conservation technique during drought, avoiding wading and swimming in flood water, and placing kerosene away from reach of smaller children to avoid fire, among others. These scenarios reinforce old knowledge and practices or may provide an avenue for players to learn hazard-specific measures or

resources they have not come across before. More importantly, the scenarios show that local people possess a wealth of knowledge, skills and resources to reduce risk (Twigg, 2015).

Figure 16. Knowledge sharing in Sai Fah! The Flood Fighter

In game-world, two main factors contribute to significant risk reduction through enhancing people's capacities. These are an enabling environments that allows access to resources, and, an opportunity to co-manage DRR measures. For example, *Riskland*, *Iggy's DRR* and *Before the Storm* highlight fixed scenarios wherein the players have the power to claim their participation in leading DRR measures such as organising flood simulation activities (*Riskland*), building sea and firewall with neighbours (*Iggy's DRR*), or negotiating funding from international agencies (*Before the Storm*). Similarly, *Impact* allows players to take the role of a specialist to decide which innovations to draw in order to solve a disruption card or scenario (e.g. superbug, increase of weather-related events, ocean acidification). These specialists use nanotechnology and artificial intelligence to counter the disruptive scenario (See Figure 17).

Overall, capacities in game-world are claimed and used by a small number of people, geographically bound, who share a common interest in building a culture of safety at three levels, that are individual, household and the community at large. In addition, most of the games' storyline encourages the player to act as an enabler to facilitate access to resources. Thus, game world portrays the player and local people as knowledgeable and skilled, capable of leading, shaping and implementing DRR measures.

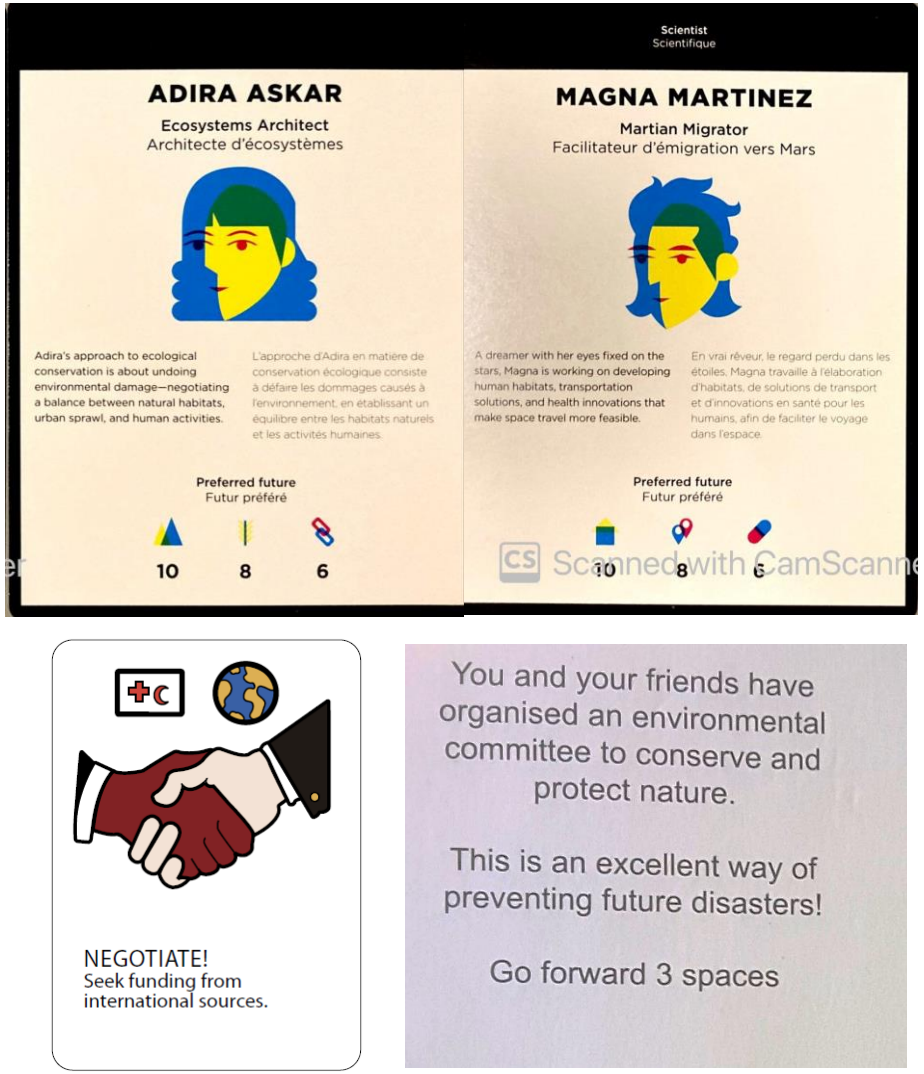


Figure 17. Enabling scenarios in game world

Table 13. Capacity in game world

Game Title & Type	Hazard	Source	Local knowledge to face hazards	Local practices to face hazards	Mutual assistance	Design and lead DRR solutions	Local leadership	Access to resources	Technical expertise	Capacity as place-based
Earth Girl Volcano Type: Video Game	Volcanic Eruption	Storytelling	✓					✓		✓
		User Interface	✓					✓		✓
		Gameplay						✓		✓
Earth Girl 2 Type: Video Game	Tsunami	Storytelling	✓					✓		✓
		User Interface	✓					✓		✓
		Gameplay						✓		✓
Sai Fah! The Flood Fighter Type: Video Game	Flood & Landslide	Storytelling	✓	✓	✓		✓	✓		✓
		User Interface	✓	✓	✓		✓	✓		✓
		Gameplay	✓	✓	✓		✓	✓		✓
Riskland Type: Boardgame	Earthquake	Storytelling	✓	✓						✓
		User Interface	✓	✓						✓
		Gameplay								✓
	Landslide	Storytelling	✓	✓						✓
		User Interface	✓	✓						✓
		Gameplay								✓
		Storytelling	✓	✓						✓

	Hurricane/ Typhoon	User Interface	✓	✓						✓
		Gameplay								✓
	Flood	Storytelling	✓	✓		✓		✓		✓
		User Interface	✓	✓		✓		✓		✓
		Gameplay								✓
	Fire	Storytelling	✓	✓		✓		✓		✓
		User Interface	✓	✓		✓		✓		✓
		Gameplay								✓
	All hazards	Storytelling	✓	✓		✓		✓		✓
		User Interface	✓	✓		✓		✓		✓
		Gameplay								✓
Impact Type: Boardgame	Sealevel Rise Increase of weather-related events Deadly Super Bug	Storytelling				✓		✓	✓	
		User Interface				✓		✓	✓	
		Gameplay						✓		
IGGY's DRR Type: Card game	Drought	Storytelling	✓	✓				✓		
		User Interface	✓	✓				✓		
		Gameplay								
	Heatwave	Storytelling	✓	✓	✓			✓		✓

		User Interface	✓	✓	✓			✓		✓
		Gameplay								
	Cyclone	Storytelling	✓	✓				✓		
		User Interface	✓	✓				✓		
		Gameplay								
	Rising sea level	Storytelling	✓	✓		✓		✓		
		User Interface	✓	✓		✓		✓		
		Gameplay								
	Fire	Storytelling	✓	✓	✓	✓				
		User Interface	✓	✓	✓	✓				
		Gameplay								
	Flood	Storytelling	✓	✓	✓					
		User Interface	✓	✓	✓					
		Gameplay								
	Earthquake	Storytelling	✓	✓						
		User Interface	✓	✓						
		Gameplay								
	Tsunami	Storytelling	✓	✓	✓					
		User Interface	✓	✓	✓					

		Gameplay								
	All hazards	Storytelling	✓	✓		✓				
		User Interface	✓	✓		✓				
		Gameplay								
Before the Storm Type: Card Game	Storm/ Typhoon	Storytelling	✓	✓	✓	✓		✓		✓
		User Interface	✓	✓	✓	✓		✓		✓
		Gameplay								✓
Word Hunt Type: Crossword puzzle	Covid-19	Storytelling							✓	
		User Interface							✓	
		Gameplay								

4.3. Disaster prevention, mitigation and preparedness in game world

4.3.1. Disaster prevention as the least represented DRR initiative

Disaster prevention is the least represented DRR initiative among the 10 games of this study. Cuny (1994) highlighted that disaster prevention include hazard-focused measures primarily designed to "eliminate or drastically reduce" (p.204) direct impact of a hazard. Both *Sai Fah! The Flood Fighter* and *Impact* present examples of disaster preventive measures as strategies that are meant to drastically eliminate a specific hazard (See Table 14). However, both games do not simulate how these preventive measures address vulnerabilities.

Table 14. Simulation of disaster prevention in game world

Game Title & Type	Hazards	Game layer	Traditional infrastructure measures	Nanotechnology & AI
Sai Fah! The Flood Fighter Type: Video Game	Flood & Landslide	Storytelling	✓	
		User Interface	✓	
		Gameplay		
Impact Type: Boardgame	Sea-level Rise; Increase of weather-related events; Deadly Super Bug	Storytelling		✓
		User Interface		✓
		Gameplay		

Impact provides a classic representation of disaster prevention by completely eliminating the effect of a deadly super bug using nanotechnology and artificial intelligence. Indeed, if technologies were to identify airborne pathogens quickly, create personalised medication and vaccines, or bacteria-proof hospitals, then drastic reduction of communicable diseases and pandemics could be achieved (See Figure 18), Furthermore, *Impact* simulates a world wherein society can afford to invest in costly innovations, and more importantly, a world where no one is excluded from acquiring these innovations.

Sai Fah! The Flood Fighter, on the other hand, simulates community-led preventive measures. As per the game's storyline, the local leaders perceive the use of sandbags as an effective barrier to prevent the river from overflowing and flood residents' houses. However, the barrier fails to hold the river-water, which leads to flooding and emergency evacuation (See Figure 19). The failure of preventive measures (e.g. flood embankments, earthquake detection), as simulated in *Sai Fah! The Flood Fighter*, highlights that prevention may not be the ultimate solution to disasters (Cuny, 1994).

Figure 18. Disaster prevention in Impact

Figure 19. Disaster prevention in Sai Fah! The Flood Fighter

4.3.2. Traditional and technological mitigation measures

Mitigation aims to reduce vulnerabilities through strategies and mechanisms that diversifies access to a range of resources (Wisner et al., 2003; Cuny,1994). Thus, the range of strategies that mitigation offers recognises that people have varying needs and access to these resources (Wisner et al., 2003).Typically, these measures consider the importance of diversifying social and economic resources, strengthening of social protection mechanisms, and local capacity (Cuny, 1994; Wisner et al., 2003).

Table 15 shows that most games highlight hazard-specific, "soft" society-oriented measures to prevent hazards and address unsafe conditions (Wisner et al.,2011). These strategies are either led by the government or the local people within a geographic location. For example, *EarthGirl Volcano, EarthGirl 2, Riskland* and *Iggy's DRR* simulate soft measures such as awareness campaigns, clean-up drives, diverse cropping, mangrove planting, and forming community or school committees (See Figure 20). In terms of "hard" engineered strategies strengthening of buildings and houses, bridge or improvement of roads or instalment of ramps were a common representation.

It is important to note that these examples reflect two approaches in DRR, that are top-down or bottom-up. For example, the gameplay of *EarthGirl Volcano*, *EarthGirl 2* and *Before the Storm* immerses a player to take a powerful role to access resources and decide mitigation strategies to minimise hazard impact. On the other hand, game scenarios in *Riskland* and *Iggy's DR*R put greater emphasis on bottom-up approaches highlighting the ability of local people to design and lead mitigation strategies.

Impact, on the other hand, offers a different set of mitigation measures through nanotechnology. These strategies highlight inventions that address fragile livelihoods and unsafe conditions in facing hazards (e.g. poor access to basic needs, lack of biodiversity resources) (Wisner et al., 2011). For example, the invention of a genetically engineered "golden rice" can potentially address food scarcity and nutrition problems. Similarly, bioengineered banana peels, coffee-grounds, algae and artificial plants become a carbon-neutral source of fuel for transportation and farming activities (See Figure 21). In game world, these mitigation measures offer promising solutions, allowing full access of these innovations in society. In reality, less-wealthy countries can hardly afford traditional mitigation measures (e.g. building retrofitting), and access to the inventions may exacerbate political and economic tensions (Cuny, 1994).

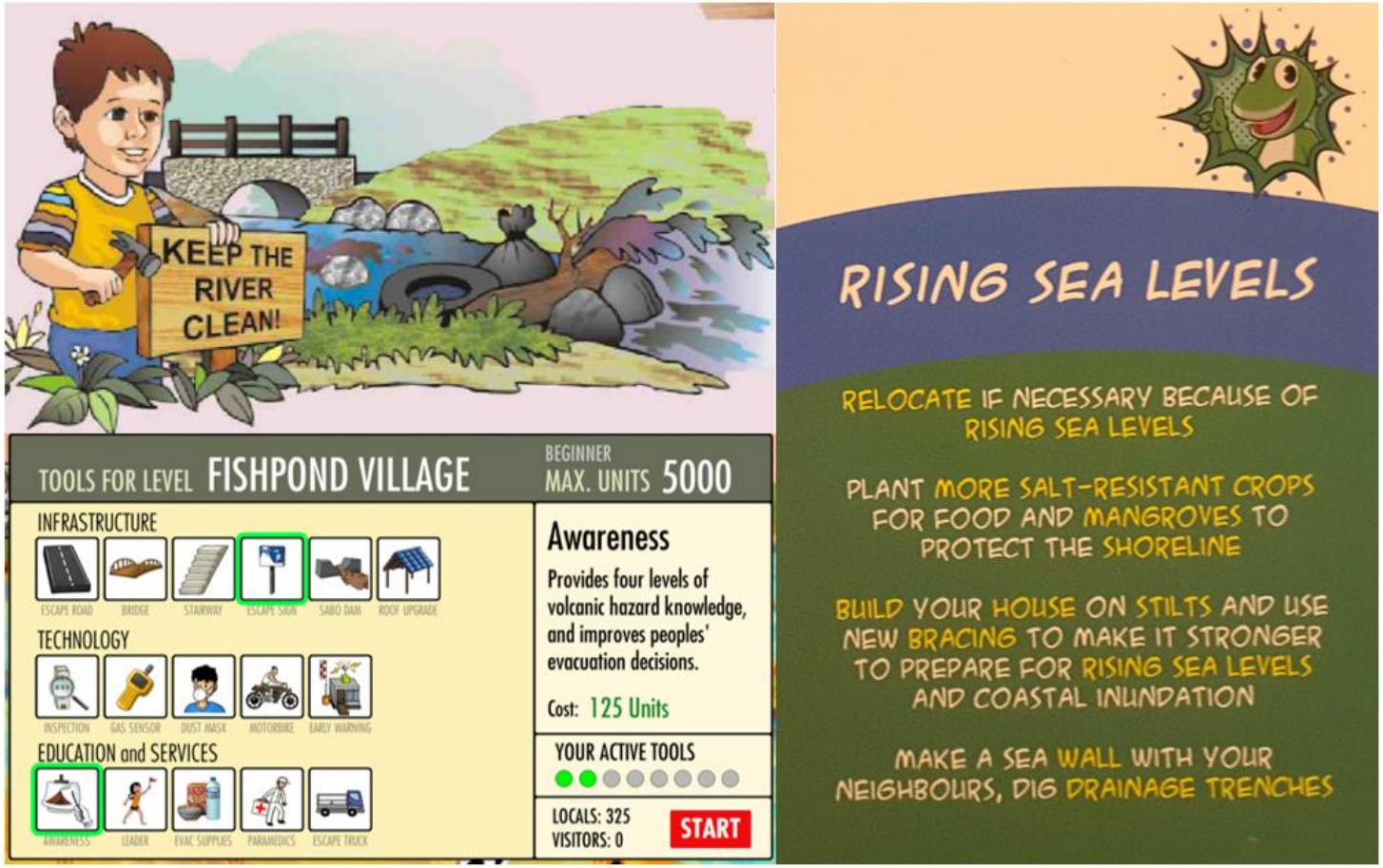


Figure 20. Soft-mitigation measures in game world

Figure 21. Technological mitigation measures in *Impact*

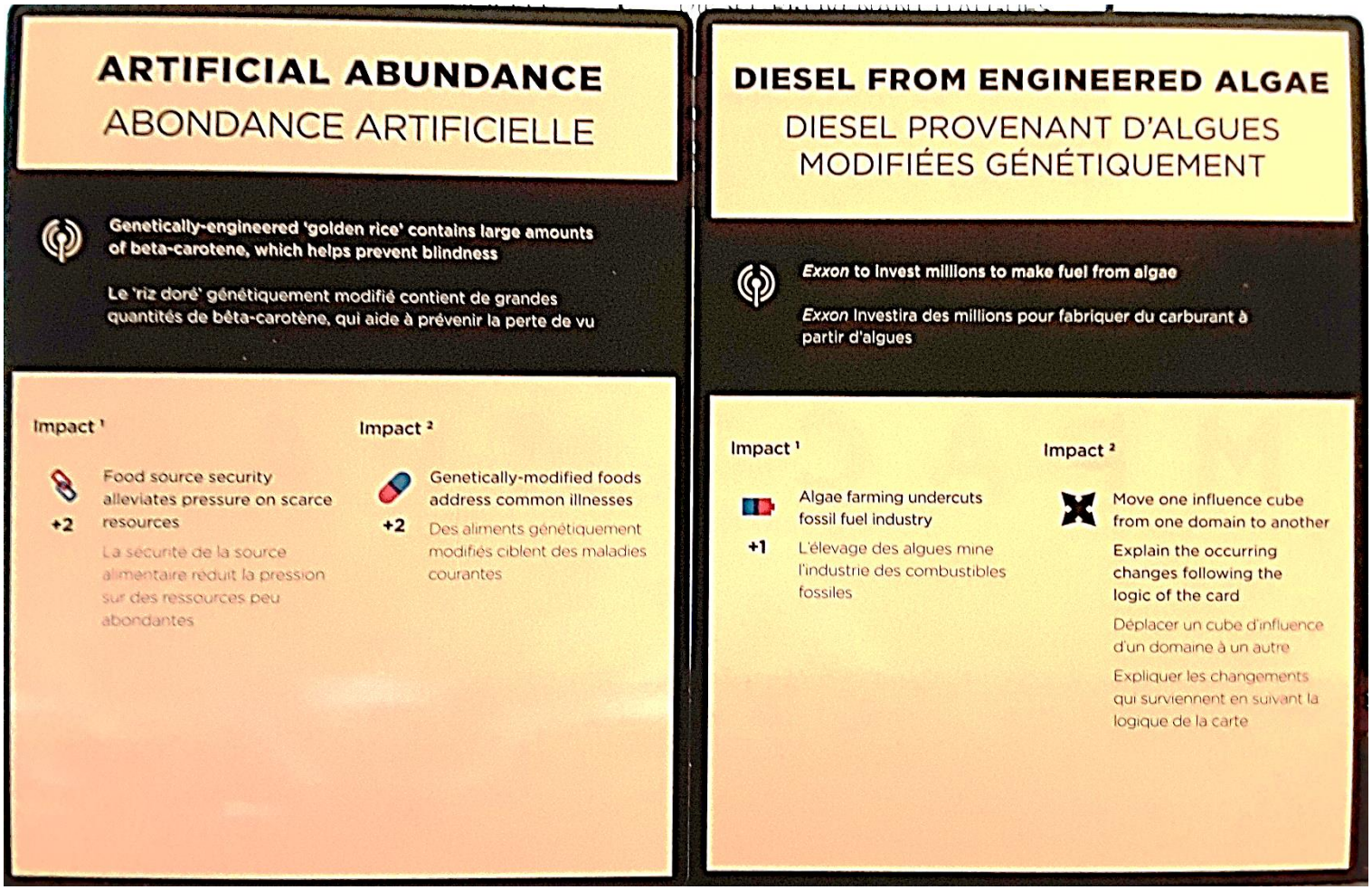


Figure 21. Technological mitigation measures in Impact

Table 15. Disaster mitigation in game world

Game Title & Type	Hazard	Game layer	Government-led hard measures	Government-led **soft** measures	Community-led hard measures	Community-led **soft** measures	Nanotechnology
Earth Girl Volcano Type: Video Game	Volcanic Eruption	Storytelling	✓			✓	
		User interface	✓			✓	
		Gameplay	✓			✓	
Earth Girl 2 Type: Video Game	Tsunami	Storytelling	✓	✓	✓	✓	
		User interface	✓	✓	✓	✓	
		Gameplay	✓	✓	✓	✓	
Riskland Type: Boardgame	Earthquake	Storytelling				✓	
		User interface				✓	
		Gameplay					
	Landslide	Storytelling				✓	
		User interface				✓	
		Gameplay					
	Hurricane/ Typhoon	Storytelling			✓		
		User interface			✓		
		Gameplay					
	Flood	Storytelling			✓	✓	
		User interface			✓	✓	
		Gameplay					
	Fire	Storytelling				✓	
		User interface				✓	
		Gameplay					
	All hazards	Storytelling			✓	✓	
		User interface			✓	✓	
		Gameplay					
		Storytelling					✓

Impact Type: Boardgame	Sea-level Rise Increase of weather-related events Deadly Super Bug	User interface					✓
		Gameplay					
IGGY's DRR Type: Card game	Drought	Storytelling		✓		✓	
		User interface		✓		✓	
		Gameplay					
	Rising sea level	Storytelling		✓		✓	
		User interface		✓		✓	
		Gameplay					
Before the Storm Type: Card Game	Storm/ Typhoon	Storytelling			✓	✓	
		User interface			✓	✓	
		Gameplay			✓	✓	
Word Hunt Type: Crossword puzzle	Covid-19	Storytelling		✓		✓	
		User interface		✓		✓	
		Gameplay					

4.3.3. Disaster preparedness as an event

Disaster preparedness assumes that institutions and local people can draw plans, establish mechanisms and identify resources in dealing with a potential threat from a hazard (Cuny, 1994, Twigg, 2015). The aim is to rapidly activate such initiatives (e.g. response, contingency plans) to protect lives and assets (Cuny, 1994; Twigg, 2015). These strategies may be enacted before, during or after a disaster strike (Cuny, 1994).

Table 16 shows that most games simulate "hard" (engineered) and "soft" (society-oriented) preparedness measures aligned with a particular hazard. Concurrently, these initiatives either mirror large-scale government activities or led by local people. Some of the commonly represented measures are instalment of evacuation signs and building of temporary shelters. Stockpiling or prepositioning of emergency supplies, monitoring of announcements through communication devices and designing safety plans are other commonly represented preparedness measures.

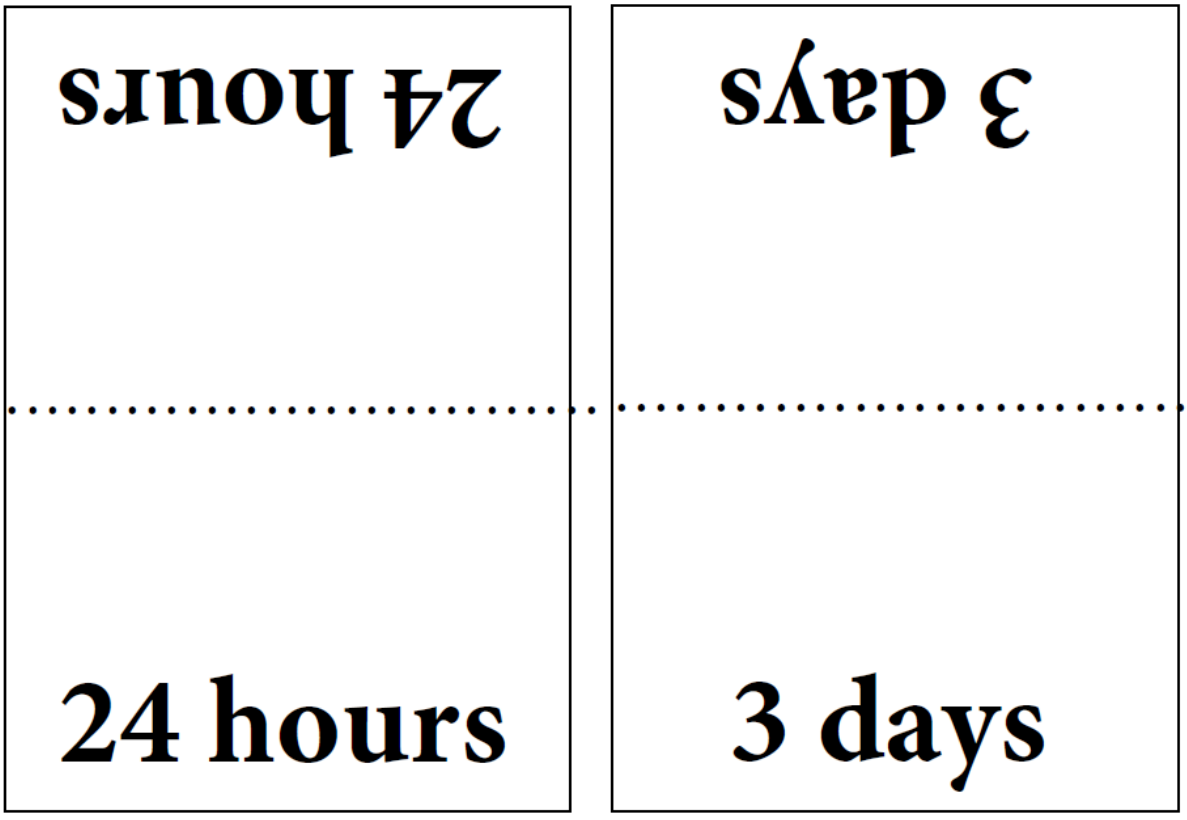


Figure 22. Disaster preparedness timeline in Before the Storm

Overall, the games offer a sense of time in managing disasters at three levels, that are individual, household and community at-large. Strategies indeed require a significant amount of time and cooperation to materialise (e.g. procurement of materials, building of temporary shelter, drafting of emergency plans). However, games have a distinct ability to bend realities (including time) in order to simulate a specific context and achieve desired goals (Pagulayan et al., 2003). In disaster serious games, this means that players and game characters revolve in a space and time, wherein preparedness is a priority and can be achieved within a certain timeframe. For example, in the game *Before the Storm*, target players (i.e. government officials, local leaders and NGO workers) are given a storm forecast to guide them which preparedness measures to enact within 24 hours, 3 days or 1-week timeframe (See Figure 22). In reality, not all countries or locality will have the ability to build temporary shelters or procure trucks or communication devices within the timeframe suggested in the game mechanics. Thus, there is a danger of simulating a reactive, rather than a proactive management, if the facilitator of the game fails to highlight that these initiatives must have been in-place or drawn prior to enactment.

Finally, the examples mentioned above highlight that most of the preparedness strategies focus on activation of emergency and relief plans. Thus, the game scenarios fail to emphasise that disasters stretch from emergency to recovery.

Table 16. Disaster preparedness in game world

Game Title & Type	Hazard	Source	Government-led preparedness measures (**hard**)	Government-led preparedness measures (**soft**)	Community-led preparedness measures (**hard**)	Community-led preparedness measures (**soft**)	Child-led preparedness measures (**hard**)	Household-level preparedness measures	Individual-level preparedness measures	Leadership in emergencies	Skilled human resource in emergencies
Earth Girl Volcano Type: Video Game	Volcanic Eruption	Storyline	✓	✓	✓	✓				✓	✓
		User Interface	✓	✓	✓	✓				✓	✓
		Gameplay	✓	✓	✓	✓				✓	✓
Earth Girl 2 Type: Video Game	Tsunami	Storyline	✓		✓					✓	
		User Interface	✓		✓					✓	
		Gameplay	✓		✓					✓	
Sai Fah! The Flood Fighter Type: Video Game	Flood & Landslide	Storyline		✓		✓		✓		✓	✓
		User Interface		✓		✓		✓			✓
		Gameplay		✓		✓		✓			✓
Riskland Type: Boardgame	Earthquake	Storyline		✓		✓					
		User Interface		✓		✓					
		Gameplay									
	Tsunami/Tidal wave	Storyline	✓			✓					
		User Interface	✓			✓					
		Gameplay									
	Tornado	Storyline							✓		

		User Interface							✓		
		Gameplay									
	Flood	Storyline	✓		✓						
		User Interface	✓		✓						
		Gameplay									
	All hazards	Storyline	✓	✓	✓	✓	✓	✓	✓		
		User Interface	✓	✓	✓	✓	✓	✓	✓		
		Gameplay									
Impact Type: Board Game	Sea-level Rise Increase of weather-related events Deadly Super Bug	Storyline						✓			
		User Interface						✓			
		Gameplay									
Iggy's DRR Type: Card game	Cyclone	Storyline		✓		✓		✓	✓		
		User Interface		✓		✓		✓	✓		
		Gameplay									
	Tsunami	Storyline						✓	✓		
		User Interface						✓	✓		
		Gameplay									
	All hazards	Storyline						✓	✓		
		User Interface						✓	✓		

		Gameplay									
Before the Storm Type: Card Game	Storm/ Typhoon	Storyline	✓	✓	✓	✓		✓	✓		✓
		User Interface	✓	✓	✓	✓		✓	✓		✓
		Gameplay									

5. Discussion

This section discusses the findings that either echoes or sets the study apart from other serious games and DRR serious games studies. In terms of commonality, the results of the study echo the benefits of serious games underlined since the 1970s (Abt, 1970; Jansiewicz, 1973) which was reiterated by other serious games studies in recent times (Di Loreto et al., 2012; Tsekleves et al.,2016; Gampell et al., 2017; Solinska-Nowak et al., 2018; Gordon & Yiannakoulias, 2020). This study confirms that serious games can simulate natural hazard scenarios (e.g. volcanic eruption, tsunami). The gameplay, in turn, mirrors hazard-focused challenges that allow players to familiarise or step into roles (e.g. government officials, community leader, teacher) where real DRR management system would not allow and would have been costly to simulate. Furthermore, although the simulation (real-time versus analog) of disasters and DRR measures varies between game typologies; serious games, as a tool, create opportunities for players to make choices and access resources. The combination of game scenarios and gameplay fosters creativity, problem-solving and altruism in a scale that traditional methods or assessment (e.g. surveys, exams) could not capture. Moreover, the results of the study reverberate the ability of serious games to cater to a range of audience from young minds to powerful decision-makers in DRR. Thus, an opportunity for dialogue may arise amongst players and or facilitators during gameplay.

Furthermore, the study posits the importance of stepping back in order to map portrayals of disaster realities and choices in serious games. The study, therefore, utilises a disaster mnemonic (Wisner et al., 2011) and serious game design framework (Winn, 2009) to assess how the game layers weave six fundamental concepts of DRR in gameplay. The results of the analysis, thoroughly discussed in Chapter 4, does not only iterate the benefits of serious games but, more importantly, emphasises to the disaster serious games community to expand realities and choices to its target players. Other studies highlight the ability of serious games to simulate natural hazards (Gampell & Gaillard, 2016; Gampell et al., 2017; Solinska-Nowak et al., 2018; Gordon & Yiannakoulias, 2020). This thesis, on the other hand, reveals a more in-depth interpretation of the concept. The results of the study iterate that the hazard acts as a vehicle to introduce other dimensions of disasters (i.e. vulnerability, capacity) and DRR measures. The researcher argues that the usual hazard-focused plot of games may be digestible and appropriate for young minds. However, this game narrative may reinforce reactive management of disasters to target players who hold powerful positions in DRR. Also, a hazard-focused plot possibly leads to interpreting disasters as a one-off event and undermines the social processes (e.g. power relations, political and economic systems) which account for most disastrous outcomes (Cannon, 1994).

Moreover, the study provides an original analysis of vulnerability in the game world. Games serve as an opportunity to create game storylines that simulate the root causes of vulnerability and tease decision-making and problem-skills of powerful authorities in DRR. Game designers may utilise almost

50 years of empirical evidence on vulnerabilities (O'Keefe et al., 1976; Oliver-Smith, 1994; Wisner, 1993; Wisner et al., 2003; Gaillard, 2010; Twigg, 2015; Kelman et al., 2017) as a basis to recalibrate potential game storylines. This type of game narrative may serve as a platform for powerful DRR actors to see the causality of disasters beyond the hazards (Watts & Bohle, 1993). Furthermore, a vulnerability-inspired storyline allows to emphasise social issues (Abt, 1970; Jansiewicz, 1973). Thus, this study calls for the serious games community to go beyond raising awareness and reclaim its space in government-related activities. Lastly, doing so may significantly contribute to narrowing gaps in integrating knowledge and actions of different stakeholders in DRR (Gaillard & Mercer, 2013).

Other studies underscore the ability of serious games to simulate DRR strategies- (Gampell & Gaillard, 2016; Gampell et al., 2017; Solinska-Nowak et al., 2018; Gordon & Yiannakoulias, 2020). This study, on the other hand, takes a different path in analysing how games simulate DRR through the concept of capacities. These resources are shared amongst a small number of people, within a geographic location, who share a common interest in building a culture of safety at three levels, that are individual, household and the community at large. Thus, capacities in game world are place-based and portray the player and local people as knowledgeable and skilled, capable of leading, shaping and implementing DRR measures (Cannon et al., 2003; Mercer, 2011; Gaillard & Mercer, 2013). In the world of DRR, however, emerging evidence of migrant remittances assert that people can support each other remotely. Capacities, therefore, although shared and endogenous to a small group of people, are not necessarily place-based (Gaillard et al.,2019). Game designers, therefore, can recalibrate storylines and extend the application of capacities beyond geographic boundaries. Furthermore, the results of the study suggest that game designers map and simulate DRR initiatives (i.e. disaster prevention, mitigation, preparedness) beyond the concept of hazards. Doing so can potentially valorise large-scale and local initiatives which may not be hazard-focused but are consistently enacted to address dynamic pressures of disaster.

Finally, the study supports the critical role of game facilitators and debriefing session as part of the overall player's experience (Abt, 1970; Solinska-Nowak et al., 2018; Gampell et al., 2020). The results of the study reveal how games can potentially skew the representation of concepts. Therefore, debriefing sessions provide an opportunity for players to reflect on key concepts that resonated to them the most (Abt, 1970; Gampell et al., 2020). Furthermore, the study reveals how conflicts may arise during gameplay. Therefore, a facilitator can diffuse and assist in processing misunderstandings or negative feelings during gameplay (Solinska-Nowak et al., 2018). The role of the facilitator also reflects the complexity involved in designing serious games. Serious games, at its core, are meant to simulate real-world topics with specific learning objectives (Abt, 1970; Aldrich & DiPietro, 2009). Disasters, on the other hand, are a multi-layered phenomenon that can be interpreted as an event and a process (Bankoff, 2011). Thus, at the outset of serious game design, the designer must be aware of the dual nature of disasters. In the end, the integration of empirical findings that encompass a specific context

(in this case disaster and DRR) can expand the learning goals of serious games and identify game elements that will best simulate disaster realities.

6. Conclusion and Recommendations

This chapter summarises the key findings from the ten non-commercial disaster serious games. It then proceeds to an outline of implications for professions working in disaster serious games community to consider, in particular, ways forward to maintain key features or reshape the contribution of serious games in the realm of DRR. Finally, the chapter concludes with a few recommendations for future research.

Chapter 1 introduced the main goal of the study, which was to investigate how non-commercial disaster serious games frame six fundamental concepts of DRR. Since the goal of the study covers both DRR and the game world, the study utilised two approaches to inform empirical findings. First, the researcher utilised Wisner et al.'s (2011) disaster risk mnemonic to uncover how these concepts (i.e. hazard, vulnerability, capacity, prevention, mitigation, prevention) correlate and form the realities of disaster and DRR. Winn's (2009) Design Play and Experience (DPE) framework, on the other hand, provides a serious game design structure to analyse how game elements (i.e. learning, storytelling, gameplay, user experience, technology) simulate a serious context in game world.

The study was able to fulfil its main goal. However, the researcher acknowledges and highlights that game world referred to in this study only represents the disaster and DRR realities of ten non-commercial disaster serious games. In this regard, the researcher argues that although the key findings represent a limited scope of disaster game world; the empirical findings ascertain a different approach in looking into both DRR and serious game world. Therefore, future research may apply the same methodological approach to expand the disaster realities portrayed by non-commercial disaster serious games. The section below recapitulates the key findings of the study.

First, the study reveals that not all serious games explicitly express their desired learning goals in game manuals or game overviews. Also, some games do not have existing storylines (i.e. crossword puzzles). However, the methodological approach utilised by the researcher offers a piece of empirical evidence on how games can express learning goals by analysing other game layers (e.g. gameplay, storytelling). The study, therefore, reveals that most disaster serious games aim to raise awareness about physical characteristics of hazards, promote DRR initiatives and build a player experience that triggers altruistic behaviour to survive the disruptive impact of hazards. Thus, at the pre-production of game design, most games intend to simulate disaster scenarios that frame disaster as a disruptive phenomenon and local people must collectively act to reduce risk Also, although most game mechanics promote competition between players; the competition only serves as a trigger for players to exhibit problem-

solving skills, creativity and critical thinking. Ultimately, most of the game storyline simulates the importance of altruism in times of adversities. Furthermore, analysis of the gameplay and storyline reveals that games can simulate top-down and bottom-up approaches to DRR. Therefore, disaster serious games can simulate an integrative process of DRR. The findings, therefore, demonstrate how interconnected each game layers are, and, in particular, how game mechanics can expand the learning goals of serious games.

Second, the study reveals that hazards and capacities are well represented in the game world. Vulnerability, on the other hand, is least represented and, when it is, is only depicted from a superficial perspective. The analysis of these three main concepts emphasises that all ten games follow a hazard-focused plot, thereby creating a gameplay that mirrors the hazard paradigm. These games immerse a player into a world that portrays disaster and DRR measures as an event that happens within a specific time, space and experienced by a group of people. Capacities, on the other hand, are a set of resources shared by these group of people and enacted in response to a particular hazard. Disaster as an event and depicted in most game storylines, portray one of the dual nature of the phenomenon (the other a process), and, the study recognises that a hazard-focused framing may be appropriate to a younger audience. Disaster as a process, roots from political and economic tensions which is out of local people's control, especially children. However, local people can demand, claim and co-manage solutions to address root causes of marginalisation. The powerful authorities, on the other hand, operate within and around the space where these root causes come from. Therefore, powerful authorities may be the better audience of a game storyline that simulates disaster as a process. Doing so, upscales the contribution of disaster serious games in government related processes but may stir pre-existing tensions in the realm of DRR. In this regard, a skilled facilitator is needed to process and create a space that allows dialogue between powerful players. Alternatively, a disaster serious game may be designed to allow dialogue between different stakeholders. Consequently, serious games may simplify disaster as a process to cater a younger audience, but again, requires a facilitator who can process this particular nature of disaster. Overall, the results, show that the dominant view of disasters and DRR (i.e. hazard paradigm) dominates not only in policies (Gaillard, 2010) but also in the game world.

Third, since all of the game plots and learning goals introduce other DRR concepts through hazard, there is a tendency for players to misinterpret that DRR only encompasses prevention of a particular hazard. However, the games did not fail to simulate DRR measures as a strategy that increases access to resources of which local people can claim and exhaust within a hazard scenario. Hence, although most disaster serious games feature a hazard-focused storyline, significant risk reduction in game world is met due to game mechanics that simulates dialogue and transfer of power between the player and game characters (i.e. local people). Moreover, most game narratives simulate trust between stakeholders through scenarios that valorise local people as knowledgeable in leading and shaping DRR initiatives. The study also reveal how games can introduce technological solutions (i.e. nanotechnology) to drastically reduce hazard impact. However, game designers must be aware that technology may ease

disaster impact, but the complex nature of disaster does not make technology as the ultimate solution of disaster. In this regard, game designers must be conscious in portraying DRR measures, most of these strategies also applies to practices at the individual, household and community level, to reduce vulnerability.

Overall, the study stresses that, firstly, disaster is a complex phenomenon to gamify. The following recommendations attempt to ease constraints in gamifying disaster and DRR. First, dialogue platforms must be in place for professions who work within the disaster serious games community to collaborate. Game designers can expand game storylines from 50 years of DRR studies to veer from the usual hazard-focused plot. Therefore, the abundance of empirical evidence that shapes the world of DRR may serve as a starting point to upscale the contribution of serious games to disaster risk reduction. This recommendation also highlights a significant limitation of the study where future research can address. The limitation refers to the failure of the study to trace whose voices (e.g. game designer, local people) were considered during the pre-production of each game. The limitation also calls for the game design community to document the process of a game's development and allow access should a document exist. The document may address gaps in game design gamify disaster and DRR. Academics and practitioners, on the other hand, can learn from game designers on possible game elements and frameworks that can best simulate a disaster reality or ascertain a gap in DRR. Thus, designing a disaster serious game may not be an easy task, but collaboration through exchange of knowledge and processes may address perennial constraints.

Second, the study highlights that regardless of game typologies, disaster serious games can simulate disasters and DRR. Although it is cost-effective to simulate volcano eruptions or tsunami through game narratives; the profession and logistics required to develop a serious game is not cheap (Tsekleves et al., 2016). Therefore, a design team must consider the size of funding to carry out the iterative process of game design and produce a good serious game. Finally, the findings stress a gap in game narratives in linking causalities of disasters to root causes of vulnerability although there is merit to portrayals of hazards in the game world. The gap identified in the study aims to inspire professions working on disaster serious games to diversify game narratives. Therefore, game design, at is core must always consider the purpose of the serious game and ultimately, for whom the game is designed for.

Recommendations for future studies:

The study was able to fulfil its main goal. However, the researcher acknowledges and highlights the following limitations worthy of further research attention. First, the game world referred to in this study only represents the disaster and DRR realities of ten non-commercial disaster serious games. Therefore, future research may utilise the same methodological approach and expand the number of disaster serious games and hopefully include commercial games which cater to a wider audience. Alternatively, future research may maintain a conservative number of disaster serious game and employ a deeper analysis of disaster and DRR realities in the game world using a hermeneutic methodological

approach. The researcher, however, may encounter difficulties in tracing pre-production reports which could be a rich resource to map and understand whose voices or realities are included in every game development. Alternatively, future research may interview game designers to understand how they construct disaster and DRR realities.

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