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Research article

Breaking the Silos: an online serious game for multi-risk disaster risk reduction (DRR) management

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Abstract. The increased complexity of disaster risk, due to climate change, expected population growth and the increasing interconnectedness of disaster impacts across communities and economic sectors, requires disaster risk reduction (DRR) measures that are better able to address these growing complexities. Especially disaster risk management (DRM) practitioners need to be able to oversee these complexities. Nonetheless, in the traditional risk paradigm, there is a strong focus on single hazards and the risk faced by individual communities and economic sectors. The development of the game and how it aims to support a shift from a single-risk to a multi-risk paradigm are discussed in detail. *Breaking the Silos* is a serious game designed to support various stakeholders (including policy makers, risk managers, researchers) in understanding and managing the complexities of DRR measures in a multi-risk (multi-hazard) setting, thereby moving away from hazard-silo thinking. What sets *Breaking the Silos* apart from other disaster risk games is its explicit focus on multi-risk challenges. The game includes different hazard types and intensities (and their interactions), different impact indicators, and (a)synergies between DRR measures. Moreover, the spread of expert knowledge between different participants and the high levels of freedom and randomness in the game design contribute to a realistic game. The game was launched during the World Bank GFDRR's Understanding Risk 2020 Forum and later played again with the same settings with researchers from the Swiss Federal Institute of Technology (ETH) in Zurich. Feedback from the pre- and post-game surveys indicates that *Breaking the Silos* was found useful by the participants in increasing awareness of the complexities of risk.

1 Introduction

Since 1980, the number of recorded disasters related to natural hazards has more than doubled (Cutter et al., 2015). The occurrence of disasters is not a geographically isolated problem, and many countries face the threat of multiple hazards (Cutter et al., 2015; de Ruiter et al., 2020). The United Nations Office for Disaster Risk Reduction (UNDRR) and the Centre for Research on the Epidemiology of Disasters (CRED) found that, globally, the last 20 years have seen a 151 % increase in direct economic losses from climate-related disasters alone (Wallemacq and House, 2018). The Sendai Framework for Disaster Risk Reduction (UNDRR, 2015b) explicitly calls for a multi-hazard and multi-sectoral approach to disaster risk reduction (DRR) practices, leading to calls from the international community to move towards a better understanding of systemic risk, i.e., accounting for the many growing complexities of risk (UNDRR, 2019). Therefore, there is a high urgency to recognize the importance of perceiving disasters holistically rather than as stand-alone single-hazard events. Nonetheless, the prevailing hazard-silo risk paradigm typically represents risk as static, both within science as well as in disaster risk management (DRM) (AghaKouchak et al., 2020; Cutter, 2018; de Ruiter et al., 2020; Scolobig et al., 2017). However, both the hazards and the impacts of multi-risk disasters can be distinctly different from disasters occurring in isolation (de Ruiter et al., 2020). Moreover, the different dynamics of multi-risk disasters introduce many challenges for DRM. DRR measures taken to decrease the risk of one hazard can have conflicting impacts on the risk of another hazard (de Ruiter et al., 2021; Ward et al., 2020). For example, wood-frame buildings may perform well in earthquakes but could sustain high damages during flooding. We refer to Box 1 for an overview of the

definitions of the different risk-related terms used in this paper.

In recent years, a large number of serious games relating to DRM have been developed. Solinska-Nowak et al. (2018) conducted a meta-analysis of DRM serious games and found that the majority focus on floods (27 out of 45 reviewed games), earthquakes (10 out 45), and droughts (7 out of 45), while storms (including cyclones, hurricanes, etc) are rarely the main hazards in a game (Solinska-Nowak et al., 2018). It should be noted that these games encompass a wide variety of game formats, including single-player or multiplayer video games, single-player or multiplayer tabletop games, and role-playing games (RPGs), making it difficult to compare them. Several studies have demonstrated the use of serious games in increasing risk awareness (e.g., Cremers et al., 2015; Mani et al., 2016; Mossoux et al., 2016; Pereira et al., 2014; Rumore et al., 2016; Solinska-Nowak et al., 2018; Taillandier and Adam, 2018). Rumore et al. (2016) quantified the effectiveness of serious games (and RPGs in particular) in increasing risk awareness, where risk awareness includes risk literacy, an enhanced collaborative capacity to address risk, and social learning.

However, there appear to be several gaps between existing games and the need to transition from a single to a multi-risk paradigm. Past games tend to focus on individual types of extreme weather-related disasters, such as coastal floods (*SPRITE*; Taillandier and Adam, 2018); river floods (*WTP for a probabilistic flood forecast*; Arnal et al., 2016); a flash flood or strong wind (*ANYCaRE*; Terti et al., 2019), floods caused by different extreme weather events such as typhoons, rainstorms, and thunderstorms (*Battle of Flooding Protection*; Tsai et al., 2020); or a specific hazard group such as geohazards (*Hazagora*; Mossoux et al., 2016). Furthermore, in previous games combinations of different hazards are not examined in one mode and, as a result, (a)synergies between DRR measures are not included. In *Hazagora*, multiple hazards can occur in 1 year (the equivalent of one round), but the game does not account for hazard interactions (Mossoux et al., 2016). *B-SaFe!* (Cremers et al., 2015) looks both at human-made and environmental hazards, but it does not account for systemic risk or DRR interactions. The *Stop Disasters!* game (Pereira et al., 2014; UNDRR, 2004) has several different modes, with each mode focusing on a different hazard type (hurricanes, earthquake, wildfire, tsunami, or flood).

Moreover, DRM commonly remains a reactive rather than proactive process (Mojtahedi and Oo, 2017). However, most DRM serious games focus on the (long-run) preparedness phase of the DRM cycle (Solinska-Nowak et al., 2018), with *ANYCaRE* being one of the few role-playing games to aim at the emergency response phase (Terti et al., 2019). Very few games include lessons learnt from past events (Solinska-Nowak et al., 2018). Several studies recognize the importance of including a participatory, multiplayer approach as a reflection of the need for collaborative approaches in DRM (Gampell et al., 2020; Solinska-Nowak et al., 2018). Finally, Taillandier and Adam (2018) also recognize other shortcomings in existing disaster risk serious games, including a focus on increasing the awareness of one particular audience (commonly the general public), optimization based on the financial aspect of risk management, and long gameplay (game time exceeding several hours).

To address the aforementioned gaps in current disaster risk serious games, we developed the *Breaking the Silos* game. *Breaking the Silos* is a multiplayer RPG that aims to raise understanding of the complexities of multi-hazard risk and asynergies of DRR measures among different DRM stakeholders. Solinska-Nowak et al. (2018) argue that RPGs, more than other game types, allow players to directly experience the uncertainty, chaos, and stress of a DRM situation. Especially multi-stakeholder negotiation RPGs have been shown to be very promising in enhancing a player's knowledge of content and process (Rumore et al., 2016). In *Breaking the Silos,* the players are a team of different decision makers and stakeholders in the DRM process who advise the president of a fictional country on the implementation of DRR measures after different disasters while considering potential (a)synergies of these DRR measures. The DRM process is mimicked by spreading knowledge and objectives throughout participants and by including randomness to the storyline. The game was developed to help various stakeholders (including policy makers, risk managers, researchers) better understand the complexities of multi-hazard risk and the potential (a)synergies of DRR measures. Unlike past games, this game includes multiple hazards and their spatio-temporal interactions. It also explicitly includes both the response and planning phase of the disaster risk cycle and promotes the examination of (a)synergies between different DRR measures. In doing so, we aim to create a game with a more realistic representation of the growing complexities of risk.

In this paper, we discuss the development of *Breaking the Silos* as a tool to enable its players to better understand the complexities of DRM in a multi-risk (multi-hazard) setting in both mitigating the impacts of an earlier disaster and in preparing for a next disaster, and we demonstrate preliminary insights from playing the game with disaster risk managers and researchers. First we describe the development and testing of the game (Sect. 2). Then, we discuss the objective, set-up, and rules of the game (Sect. 3). Third, we report on the implementation of the game and provide preliminary findings on how the players experienced the game and reflected on the potential impact of the game within the field of DRR (Sect. 4). Finally, we provide an outlook on potential improvements to the game and concluding remarks (Sect. 5).

2 Game development and testing of the game

The game was originally conceived as a face-to-face board game for the World Bank GFDRR's Understanding Risk

We use the definitions of multi-hazard below, and we refer to the different hazard interrelations according to a major recent review in the UK (Ciurean et al., 2018):

- ***Disaster risk*** can be defined as a function of hazard, exposure, and vulnerability, where ***hazard*** is defined as a potentially damaging event; ***exposure*** is defined as the elements subject to damage and losses as a result of a hazard; and ***vulnerability*** is defined as a community's susceptibility to the impacts of a hazard as influenced by a community's physical, social, economic, and environmental conditions (UNDRR, 2016).
- ***Multi-Hazard*** **is** (1) the selection of multiple major hazards that the country faces and (2) the specific contexts where hazardous events may occur simultaneously, cascading, or cumulatively over time (Gill and Malamud, 2014).
- The term ***consecutive disasters*** has been used to describe two or more disasters that occur in succession and whose direct impacts overlap spatially before recovery from a previous event is considered to be completed (De Ruiter et al., 2020). These can include a broad range of multi-hazard types, such as those listed above.
- ***Disaster Risk Reduction (DRR)*** aims at preventing or decreasing the existing disaster risk and increasing resilience (UNDRR, 2016).
- **Disaster Risk Management (DRM)** is the use of DRR policies and measures to prevent or decrease disaster risk (UNDRR, 2016).
- ***(A)synergies of DRR measures*** are potential adverse effects of DRR measures. DRR measures that are aimed at reducing the risk of one hazard can have opposing or conflicting effects on the risk of another hazard (De Ruiter et al., 2021).

Box 1. Glossary of terminology on risk, multi-hazards and their interrelations.

2020 Forum (UR2020), which was planned for May 2020 in Singapore. As a result of COVID-19, UR2020 took place fully remotely in December 2020, and we therefore developed the first version of the game (reported in this paper) to be played remotely. Whilst we report on this online version in this paper, it can easily be used in a face-to-face setting once the pandemic is contained. The testing phase was spread out over the course of a month to allow for an iterative process to develop and improve the game.

2.1 Game objective

Breaking the Silos is an RPG in which players aim to reduce the impacts of separate and consecutive disasters in a fictional country or region under certain time and financial constraints. The game was designed to help decision makers and practitioners better understand the complexities of multi-hazard risk and the potential (a)synergies of DRR measures. It is designed as a narrator-led, RPG board game in which DRR measures to be implemented are collectively discussed and ultimately decided by the leader of the game board (the president). Each player is assigned a role and is provided with information about their own expertise and responsibilities. They are also provided with information about their own relationship with some of the other roles. Information about different hazard types, DRR measures and their effects, (a)synergies, and costs are spread over all roles. Therefore, meeting the game's objective can only be achieved by collaborating. The impact of the decisions taken is assessed at the end of each round by checking three criteria (explained in the next section) and comparing the impact of a new disaster with and without the DRR measures implemented following a previous disaster. The team needs to minimize the disaster impacts.

2.2 Game set-up

In many disaster situations, DRM commonly remains a reactive rather than a proactive process (Mojtahedi and Oo, 2017). To reflect this, it was decided to develop a game that starts right *after* the occurrence of a disaster. To make the game of interest to a wide user audience, commonly (consecutively) occurring disasters such as tropical cyclones, droughts, and floods were selected. In line with common indicators of disaster impacts (Cardona, 2005; de Ruiter et al., 2017; UNDRR, 2015a), the game includes damages to people, buildings, key economic sectors (such as agricultural areas), and critical infrastructure (including hospitals and airports). Disasters can occur at three different intensities, namely, low, medium, and high. We set discrete vulnerability curves for each hazard type and indicator to determine the number of people, buildings, and critical infrastructure that are affected by the hazard. For example, we assume that hospitals, usually designed with higher design standards,

have a lower failure probability and will therefore not be affected by a low tropical cyclone nor by a drought of any intensity.

The implementation of DRR measures can have both positive and negative effects on the overall risk faced by a community. Therefore, the game uses DRR measures and their potential (a)synergies as identified in recent scientific literature (e.g., de Ruiter et al., 2021; Fraser et al., 2013; Ward et al., 2020). The DRR measures can have multiple potential advantages or disadvantages for one or more hazard types. The changes in risk due to the impacts of hazards and the effects of the implemented DRR measures are automatically calculated in the calculator tool used by the moderator based on predefined conditional vulnerability curves for each indicator and consecutive sequence of disaster. The (a)synergies of multiple DRR measures are reflected by multiplying values to the vulnerability curves before updating the indicator layers (population, buildings, etc.) A value of 1 indicates no effect on impact; a value higher than 1 increases exposure and lower than 1 decreases exposure.

The game was designed as an RPG as several studies have demonstrated the effectiveness of RPGs in mimicking the uncertainty of a post-disaster DRM situation (e.g, Solinska-Nowak et al., 2018). Research has demonstrated that DRM requires the involvement of different stakeholders including local to national government representatives, administrative staff and NGOs, and representatives of key sectors (Modgil et al., 2020; Mojtahedi and Oo, 2017; Solinska-Nowak et al., 2018). To reflect this, the roles for our game were developed such that there are close ties between some of the stakeholders, while others have conflicting preferred DRR measures, knowledge, and different willingness to spend money on DRR measures. The storylines are fictional, as the series of events and intensity are randomly selected, but draw experience and learning from historic events (e.g., the 2019 consecutive disasters hitting the African east coast including cyclones Idai and Kenneth, the summer droughts, winter floods and subsequent crop losses). The moderator can decide to select a series of hazards themselves instead of using the random generator. This may be desirable if the moderator wants to highlight specific temporal or spatial risk dependencies. The storyline, the hazard types, the possible DRR measures, and the roles can be adjusted or new ones can be developed based on the training needs of the players. Finally, to prevent any association with an existing country, the game uses a fictional currency (coins).

2.3 Role of the moderator

The game requires a moderator, who can be thought of as a game master. The moderator is not actively participating in the game but narrates the storylines, runs the impact and DRR calculations in the background, and keeps track of time. All participants (and the moderator) communicate using an online meeting software such as Teams, Zoom or Skype. The game board and players' cards are all shown on the MIRO platform, which is an online whiteboard for visual collaboration (see Fig. 1). Actions in the gameplay take place on this game board. Additionally, the moderator has access to a calculator tool for keeping track of the score. The calculator tool is a series of spreadsheets containing the exposure, hazard, and vulnerability relationships between the disasters. As the moderator enters the DRR measures selected by the team, summary tables are automatically updated. These tables indicate whether the team met the round's objectives, the updated budget for the next round, and the difference in risk with the DRR measures selected to a situation in which no DRR measures would have been taken (in terms of population, building, and critical infrastructure impacted). During the games played at UR2020 and ETH Zurich, the moderators were part of the research team. While the moderators' guidelines and storylines (Sect. S1 in the Supplement) are self-explanatory, we do recommend moderators to first play the game themselves before moderating the game.

2.4 Learning through debriefing

While often lacking, a debriefing element in serious games is of utmost importance to support the learning process (Crookall, 2010; Kolb et al., 2014). It is even argued that real learning comes not from playing serious games but from the debriefing element (Crookall, 2010). Several more recent studies have addressed this by including feedback on actions within the game, so-called "learning by doing", which can increase learning (Solinska-Nowak et al., 2018; Terti et al., 2019). Therefore, we decided to create three rounds, which demonstrate disaster and DRR interactions and allow players to change their approach to DRM in each round. Each round starts after a disaster, and the team is asked to agree on the implementation of (a set of) DRR measures. We expect to see the teams responding to the particular hazard type that just caused a disaster rather than to also anticipate future risk of other hazards despite information on the role cards informing players of the risk of other hazards. Each round begins after a new disaster, and with the moderator explaining the impacts of that disaster as well as highlighting the impacts of DRR measures that were taken in the previous round. This intermediate debriefing that follows each round and is led by the moderator was designed as such to enable a reflection on the effects of the actions taken, to allow players to adjust their behaviour in subsequent rounds, and to experience the effects of changing one's behaviour. We expect that this influences the team's behaviour during the next round. Finally, it was decided to include a discussion that takes place at the end of the game to enable players to reflect on the effects of the debriefings. The discussion can be supported by looking at the overview tables that summarize the actions taken after each round and the effects of these actions on subsequent disaster impacts.

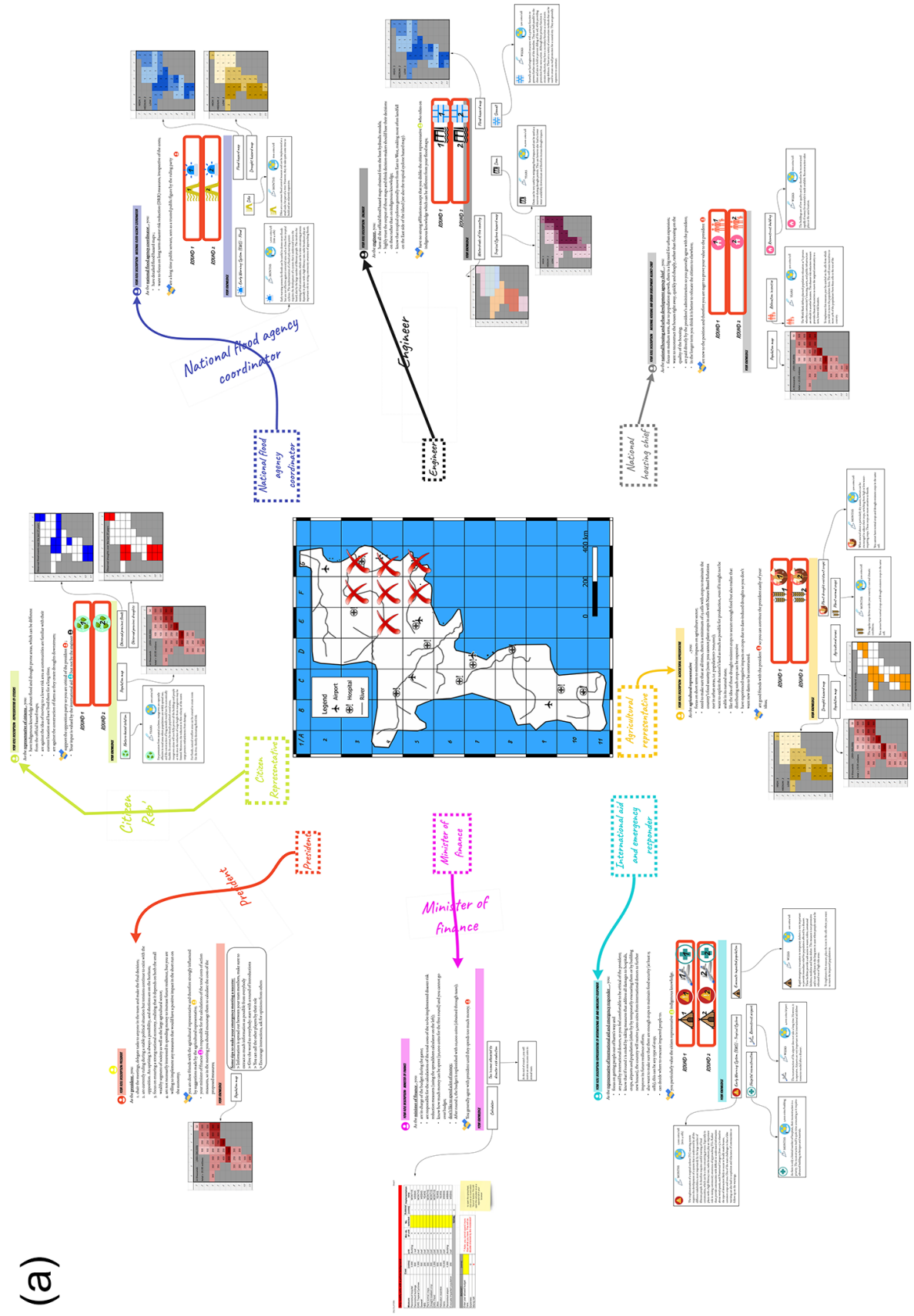
(a)
National flood agency coordinator
Engineer
Citizen Rep'
Citizen Representative
President
Minister of finance
Agricultural representative
International aid and emergency responder
Legend
Airport
Hospital
River

Figure 1.

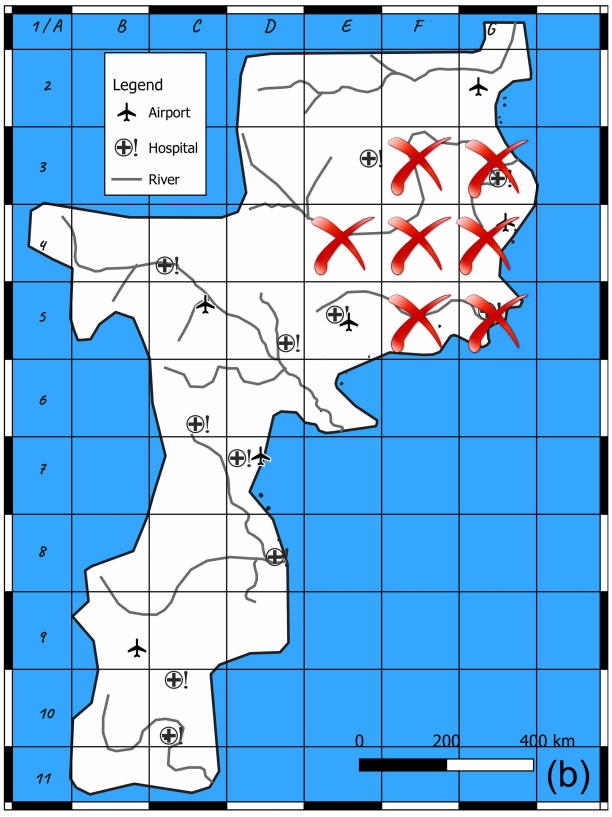

Figure 1.

During the development of the game, we estimated that the first round would take 30 min and the second round 20 min. Based on feedback received during the testing phase, each round was broken down into two parts. The first part is meant for a general discussion between the team members. This is especially important and time consuming during the first round as players need to understand their own role and that of the other members of the team and to get comfortable with the MIRO environment. The second, shorter, part of each round is allocated to make final decisions about which DRR measures to implement and to place them on the map (Fig. 1b).

2.5 Different game versions

The primary game version reflects a fictional country, with a strong economic dependence on the agricultural sector, facing tropical cyclones, droughts, and floods. Different game versions can be developed, each with their own storyline, socio-economic and political characteristics, hazard types, available financial funds, DRR measures, and DRM roles, to adapt the game to players' specific needs or hazard environments. For example, future game versions could include the occurrence of a pandemic, outbreak of a vector-borne disease, or natural technological disasters. The role cards can also be adjusted such as to mimic different government systems.

2.6 Testing of the game

Prior to its launch, the game was tested three times with the help of masters students in geo-related fields (hydrology, earth sciences, and global environmental change). Each test game was played 2 weeks apart to allow for an iterative process of implementing suggestions from the participants regarding game design and gameplay. As the design of the game changed over the course of the testing phase, the participants were not asked to complete the questionnaire. The testing of the game provided very valuable feedback on the game's design, the clarity and level of involvement in the game of the different roles, the conflicts between them and their preferred DRR measures, the balance between the available budget and costs of the DRR measures, and the time component. Finally, the testing phase also allowed for the training of the moderators. As has been suggested by other studies (e.g., Tsai et al., 2020), the moderators learnt the game first by playing it without receiving any background information (similar to the other test participants).

3 How to play the game

In *Breaking the Silos*, players are assigned their role at the start of the game. Before the start of the game, each player reads their role card, which provides them with detailed information about the DRR measures they can implement (these are unique for each role) and goals they need to meet. The game consists of three rounds. At the start of each round, the moderator selects a disaster and impacted area and informs the team of the impact that the disaster caused. In each round, the team has a tight budget and time restriction to address the post-disaster situation and to prepare for a next disaster by implementing DRR measures. After each round, the moderator calculates the effects of the implemented DRR measures on the next disaster.

3.1 Final game design

As Fig. 1a shows, the MIRO board consists of a map of the team's fictional country (placed in the centre of the board) surrounded by the different players' role cards. The game map (Fig. 1b) shows the areas impacted by a disaster (the red crosses), the location of selected critical infrastructure (the main hospitals, airports), and some geographic features (e.g., rivers and coastline). The game includes eight roles: the president, the minister of finance, the representative of international aid and emergency responder, the agricultural representative, the national housing and urban development agency chief, the engineer, the national flood agency coordinator, and the representative of the citizens. Each of the role cards has the same structure (Fig. 1c). It explains to the

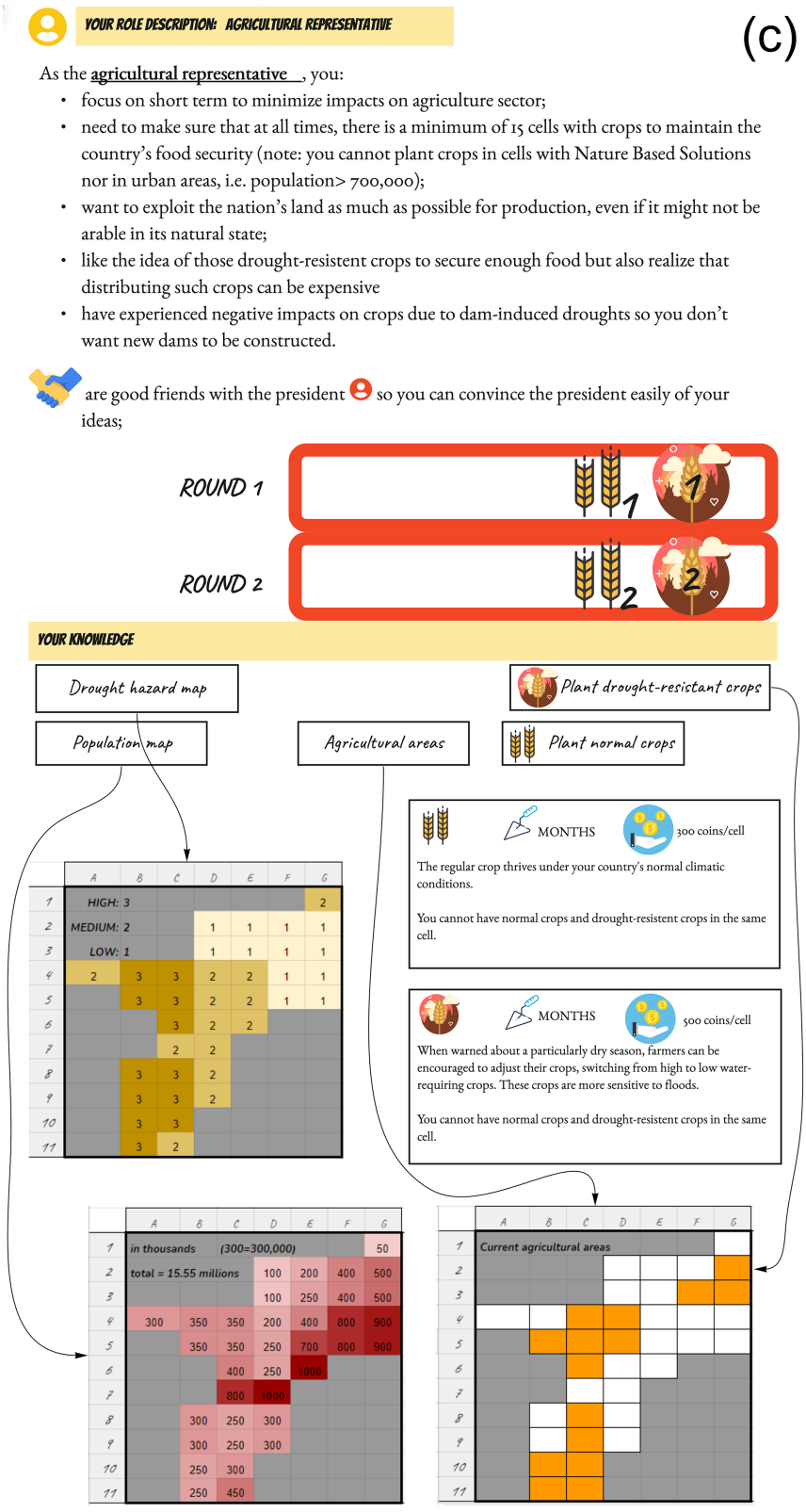

Figure 1. Panel **(a)** shows an overview of the game board with the map of the country in the middle and the roles and their descriptions around it. To support navigation and limit players searching the game board, the map board shows where information of each role can be found. Panel **(b)** zooms in on the main board game showing the maps of the fictional case study area and area impacted by a disaster. Panel **(c)** zooms in on one role card (here the agricultural representative is shown) giving a description of their role, expertise, specific hazard or exposure knowledge and DRR measures.

player the characteristics of their role including some background information about their position in the team, their relationship with some of the other members of the team, and the specific DRR measure(s) that their role can implement. It also provides some detailed knowledge on these DRR measures, including information such as their costs, their advantages, limitations and potential synergies with other hazard types, the time it takes to implement them (discretized between weeks, months, or years), and (depending on the role) information about particular hazards and demographic information. Each DRR measure has a different symbol, and a numerical subscript is used to indicate the round during which these DRR measures can be implemented (Fig. 1c). The types of measures that a role can implement do not change per round, but some of the DRR measures cannot be built in particular cells of the map, e.g., because they cannot be built together with another DRR measure or because they are invalid (e.g., a seawall can only be built in coastal cells), and some of the descriptions of DRR measures warn the player of potential (a)synergies (Fig. 1c). For example, the agricultural representative can plant both normal and drought-resistant crops (Fig. 1c). They have the following information: the costs of the different crop types (drought-resistant crops are more expensive than regular crops), drought-resistant crops are more vulnerable to floods, to meet the country's needs they need at least 15 cells of crops, and neither of these crops can be planted in densely populated cells or in cells where nature-based solutions (NBSs) have been built. The president, the national housing and urban development director, and the citizen representative roles have information about the population per cell. Conflicts can arise when, for example, the citizen representative wants to implement NBSs in the same cell where the agricultural representative wants to plant crops or if crops are in the downstream area from where the engineer wants to build a dam to decrease flood risk or upstream droughts.

While it is possible to play the game with fewer than eight players, we advise at least six people to ensure coverage of most expertise concerning the hazard types and DRR measures and uncover important asynergies. The president is responsible for taking the final decisions and the minister of finance has information about the available budget and expenses. In case fewer than eight players are playing, this would mimic the concept that in real life important stakeholders can also be absent from key meetings. Alternatively, it can be decided to add the tasks of the absent player to other player(s). Note that even though participants can navigate anywhere on the MIRO board and in theory could read about other roles, in practice there is limited time to do this.

3.2 Gameplay

Figure 2 shows an overview of the different actions per round, the actual playing time, and the temporal dimension. Before the start of the game, the moderator distributes the roles among the players, randomly selects a series of three hazard types (tropical cyclone, drought, flood), intensity (low, medium, and high), size of area impacted (integer between 5 to 15 cells), and time between disasters (weeks, months, years). They also select on the map which contiguous cells will be impacted by the event. These selections are not shared a priori with the players and will define the storyline of the game. Apart from the geographical selection of the cells impacts, all other characteristics are randomly selected from a uniform distribution and assumed to be independent. Therefore, each hazard type, level, number of impacted cells and timescale have respectively a 33 % chance of being selected (except for the number of impacted cells, which has a probability of $1/16$). Hence, there is a $(1/3)^6$ probability of having a storyline with three consecutive hazards of the same type and intensity. They can still however have a different number of cells impacted and location. The moderator introduces the players to the overall game set-up and leaves some time for the players to read their role card to learn about their role and possible DRR measures that they can implement. They then read the background story to give all players' general information on the setting of the game.

3.2.1 Round 1

- The game starts after the fictional country is hit by a disaster and mimics a situation in which the president brings together their team of key experts and stakeholders to address the situation and to decide whether they want to implement DRR measures and if so which. The moderator adjusts the map in the centre of the board to highlight the cells that were impacted by the disaster and narrates the storyline (see Sect. S1). They encourage the team to give their fictional country a name (to increase the team's sense of commitment), then set the timer on the MIRO board (visible for all players to start the first round), and give the floor to the president. The moderator sets a timer for 20 min.

- As information is scattered between different roles, the team needs to try to exchange knowledge about all aspects of risk. On their role card, the president is actively encouraged to give the floor to all team members to share their insights and to make a pitch for their preferred DRR measures. The minister of finance is responsible for keeping an eye on the budget as the team is not allowed to spend more than the available budget. While the moderator should interfere as little as possible with the team, they may intervene to help ensure respectful interactions between players and to ensure that all players are included in the discussions.

- When the timer goes off, the moderator tells the president that they have 10 min to make a final decision and sets the timer. Team members are responsible for placing their DRR measure(s) on the map in the cells in

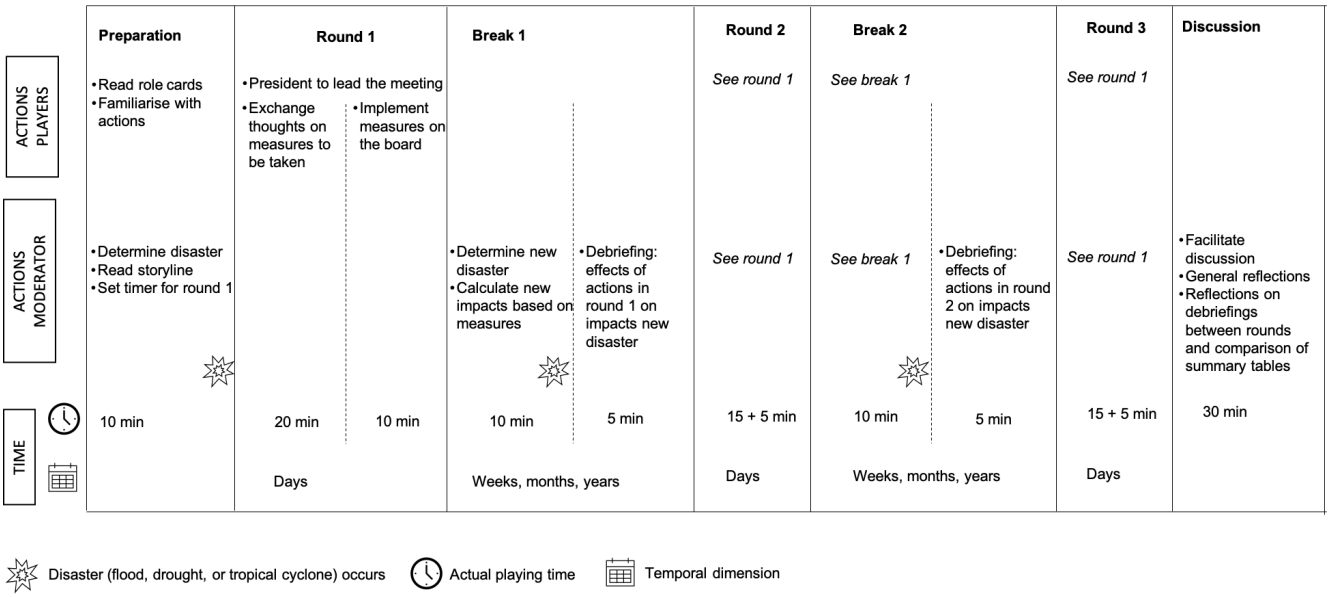

Figure 2. Overview of the different rounds of the game, the actions to be taken by the players (top row) and the moderator (middle row), and the actual playing time and temporal dimension (bottom row).

which they want to implement their DRR measure(s). The minister of finance needs to complete the calculator to ensure that the team remains within its budget. The end of the second timer signals the end of round 1 and a break of 10 min for participants to relax. During the game, participants are asked not to discuss gameplay outside of the game (for example during breaks) to ensure that reflections on gameplay and on the debriefing take place within the game's environment.

During the break, the moderator inputs the DRR measures into their calculator tool, not accessible to the players (see Sect. S2), and checks whether the team remained within budget. If the team spent more than its allowed budget, the moderator randomly removes a DRR measure to stay within the budget. As part of the international aid and emergency responder's role, the team can receive extra funds if by the end of round 1 they meet a set of short-term recovery objectives including: (1) the rebuilding of damaged airports and hospitals, (2) evacuating or rebuilding homes for the people who were impacted by the first disaster, and (3) restoring food production (agricultural needs); see Fig. 3a. The moderator checks whether the team meets these requirements. Finally, the moderator prepares the board for the start of the second round by adjusting the country map to show the location of the impacts of the second disaster. The calculator tool automatically assesses the impacts of the new disaster and what the impacts would have been had the team not taken any DRR measures at the end of round 1 as well as the difference between the two (the achieved change in risk); see Fig. 3b. Note that due to (a)synergies of DRR measures, both an increase and decrease in risk is possible after the implementation of DRR measures. Both the short-term recovery objectives table and the overview table are then copied into the MIRO board.

3.2.2 Round 2

At the start of round 2, the moderator tells the players whether they met the requirements of the international community to receive extra funds. They also communicate the updated budget to the minister of finance (see Sect. S3). They then continue narrating the story, telling the players about the second disaster and the impacts and the effects of their DRR measures. Here, the moderator briefly discusses with the players possible reasons for the observed change in risk (increase, decrease, or constant). For example, the team may have spent its budget on protecting against one hazard type only, but the new hazard is of another type. Also, if the time between the two disasters is shorter than the DRR implementation time, this measure is not operational at the time of the second event (even though funds have already been spent). This is indicated on the board with the addition of a crane symbol on top of the affected DRR measures. The second round then follows the same steps as round 1. During the break, the moderator follows the same steps as detailed above.

3.2.3 Round 3

The final round can be played partly or completely depending on the available time. At a minimum, it is recommended to inform the players of the effects of their DRR measures on a third disaster, by sharing the overview tables.

(a)

Element	Recovery objectives
Evacuate people or rebuild	NOT MET!
Hospitals	NOT MET!
Main airport	NOT MET!
Agricultural needs	NOT MET!
	No extra aid :(

(b)

	(2)	(3)	(4) = (2)-(3)
	New event: very severe drought		
Summary	Impacts of new event	Impacts w/o previous DRR measures	Your achieved risk change
People	24 300	24 300	0
Buildings	0	0	0
Hospitals	0	0	0
Main airport	0	0	0
Agricultural needs	5	5	0

Figure 3. Panel **(a)** shows the four elements that, if damaged, need to be recovered to be eligible for international aid in the subsequent round. All requirements need to be met to be eligible for international aid. Panel **(b)** shows the calculator tool, which automatically assesses the impacts of the new disaster and what the impacts would have been had the team not taken any DRR measures at the end of the previous round(s). In this case, DRR measures taken during earlier rounds did not increase nor decrease the impacts of the next disasters.

At the end, the participants are encouraged to reflect on the game. The moderator first asks the players to share their general thoughts on the game, and they ask the players to discuss their decision-making process, to reflect on their behaviour in different rounds, and to discuss the effects of the information provided during the debriefing.

4 Game implementation and preliminary findings

4.1 Implementation

Breaking the Silos was first played during the virtual UR2020 Forum in December 2020 and subsequently by colleagues from the Swiss Federal Institute of Technology (ETH) in Zurich in February 2021 using the same settings. UR2020 is a free-of-charge event that attracts "an open and global community of over 9000 experts and practitioners interested and active in the creation, communication, and use of disaster risk information". The game was launched within the session *Breaking the Silos: from single to comprehensive multi-risk frameworks* (https://understandrisk.org/breaking-the-silos-from-single-to-comprehensive-multi-hazard-risk-frameworks-2/, last access: 12 February 2021). Due to logistical constraints, a limited number of participants could take part in the session, and we were able to play the game on two separate boards (i.e., two teams). In order to better compare gameplay between the teams, they both played the national game and faced the same hazards, namely, a tropical cyclone of medium intensity at the start of round 1 (its location is identical to that shown above in Fig. 1b), a drought of high intensity at the start of round 2 (Fig. 4a), and a flood of medium intensity at the start of round 3 (Fig. 4b). Due to the limited time available in the UR2020 session (1 h for the game), the game consisted of two full rounds and the start of a third round. The impacts of a third disaster and the DRR measures from rounds 1 and 2 were discussed, but the round 3 was not completed. Both games were moderated by trained moderators. At ETH, we also played the game on two separate boards (Fig. 4c and d), and the series of events, intensity, and location of the affected areas were kept the same to allow for comparison for the purpose of this study.

Even though the sequence of disasters and storyline were similar, the teams adopted different DRR strategies as shown in Fig. 4. This is also reflected in Fig. 5, which shows the different investments in DRR strategies between round 1 and 2, demonstrating the many possible choices and outcomes of the game, underscoring its high degrees of freedom. It appears that during all games, teams narrowed down the number of implemented DRR measures between round 1 and 2. While in round 1, on average, teams implemented seven different DRR measures, they implemented on average only 3 measures in round 2. Moreover, while in round 1 only one team invested in early warning systems for tropical cyclones and no one invested in dams, in the round 2 three teams invested in the tropical cyclone early warning system and two teams spent half of their investments on dams. We refer to Sect. S4 for a detailed overview of the coins spent per round (per DRR measure and per team).

4.2 Preliminary findings

We assessed the opinions of the participants about gameplay and learning using a pre- and post-game survey (Table 1). Unlike other studies, such as Tsai et al. (2020), who created a survey consisting of 93 questions, our survey was intentionally kept short with a set of 5 and 7 questions for the pre- and post-game survey. While in theory using a large number of questions can provide very detailed feedback, the risk of receiving many incomplete surveys increases significantly. Moreover, due to the limited time available during both the UR2020 and the ETH sessions, our surveys had to be concise. The surveys consist of open and closed questions. Similar to other studies (e.g., Pereira et al., 2014), the closed questions use a five-point scale and were designed based on the intrinsic motivation inventory (IMI; a multidimensional

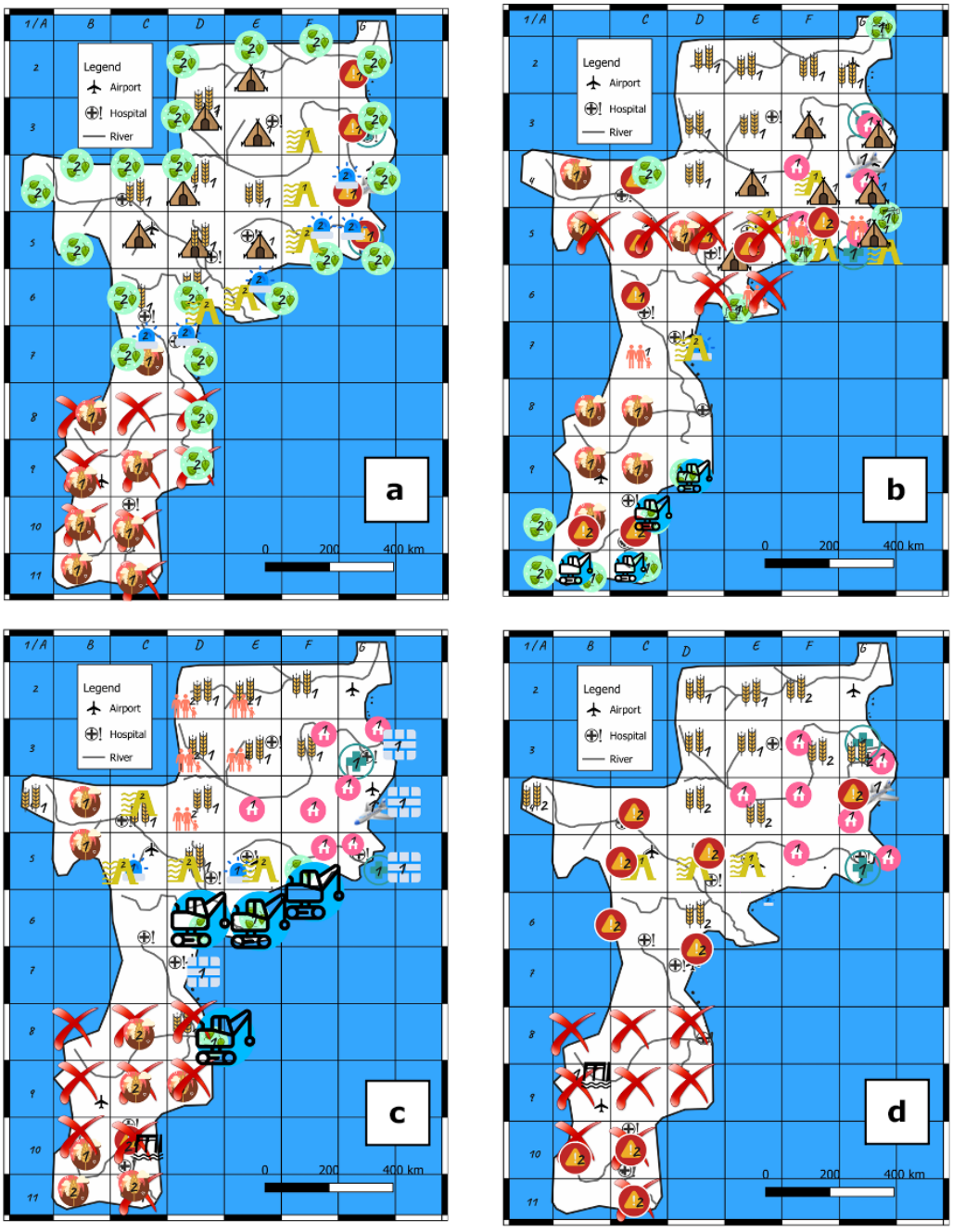

Figure 4. Final boards for teams 1 and 2 during UR2020 (respectively panels **a** and **b**) and teams 3 and 4 during the ETH session (respectively panels **c** and **d**). DRR symbols with a "1" or "2" denote measures implemented respectively during round 1 or 2. In panel **(a)**, the red crosses show the location of the second disaster (the high-intensity drought). In panel **(b)**, the red crosses show the location of the third disaster (the medium-intensity flood).

measurement device used to measure participants intrinsic motivation and their subjective experience in experiments). We purposefully kept these surveys short in order to maximize the participants' feedback. The pre-game survey consists of five questions focusing on participants' professional background and DRR aspects and challenges they encounter in their work, while trying not to influence the players' multi-risk and DRR (a)synergies awareness. The post-game survey consists of three questions that assess learning and recommendations to improve the game.

In the pre-game survey, the majority of the participants of both UR2020 and ETH reported working in a field related to the implementation or evaluation of DRR measures (respectively 57 % and 80 %). Of the respondents who reported

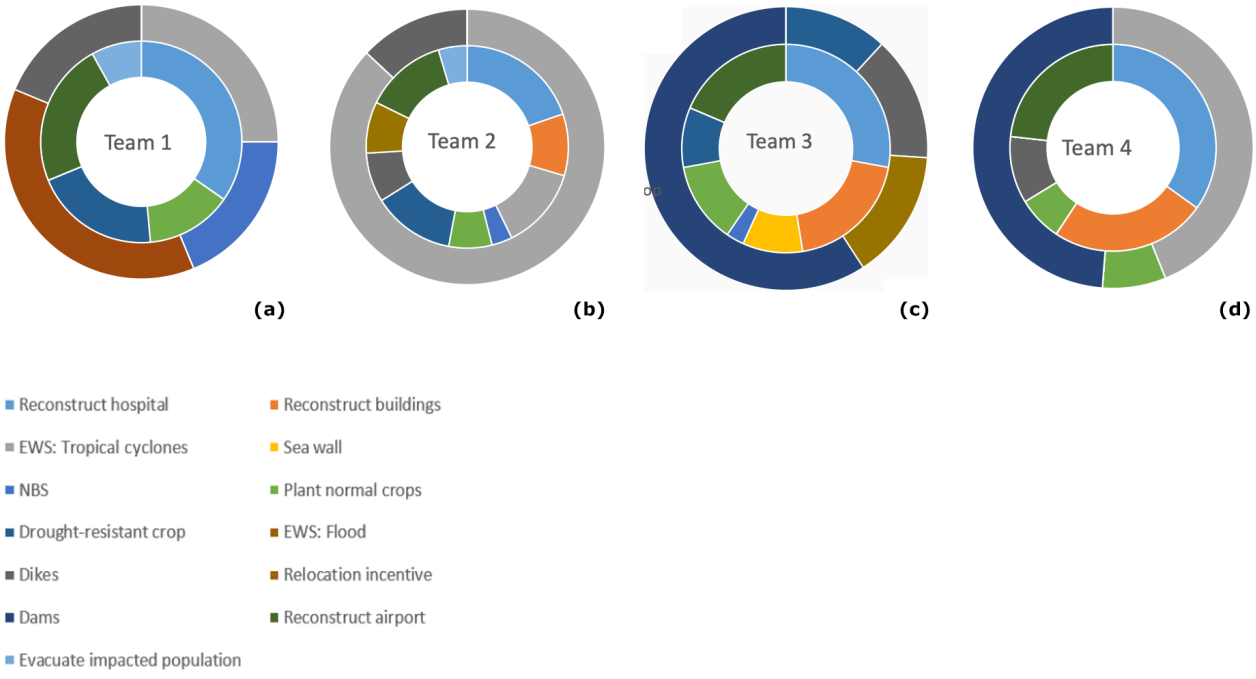

Figure 5. Distribution of the investments in DRR measures during round 1 and round 2 for teams 1 and 2 during UR2020 (respectively panels **a** and **b**) and teams 3 and 4 during the ETH session (respectively panels **c** and **d**).

Table 1. Pre- and post-game survey questions used at UR2020 and the session at ETH.

Pre-game survey questions	Post-game survey questions
(1) What type(s) of hazards do you work on in your professional role? *(open question)* (2) Does your work relate to the implementation and/or assessment of disaster risk reduction measures? *(yes/no)* (3) If so, what aspect(s) do you account for in evaluating a DRR measure? (a) costs of implementation; (b) short-term benefits in decreasing risk of 1 hazard; (c) long-term benefits in decreasing risk of 1 hazard; (d) short-term benefits in decreasing risk of at least 2 hazards; (e) long-term benefits in decreasing risk of at least 2 hazards. (4) I feel well-equipped to assess and/or implement DRR measures. *(agree – not agree 5-point scale)* (5) What main challenges do you face in implementing/assessing DRR measures? *(open question)*	(1) I enjoyed playing the *Breaking the Silos* game. *(agree – not agree 5-point scale)* (2) Did you feel immersed in the game world and in the role of decision-maker? *(agree – not agree 5-point scale)* (3) I feel that the game gives a realistic representation of the complexities of decision-making on DRR. *(agree – not agree 5-point scale)* (4) Playing the *Breaking the Silos* game has increased my understanding of the complexities of DRR. *(agree – not agree 5-point scale)* (5) As a result of playing the game, I plan to change my future actions related to DRR planning/assessment. *(agree – not agree 5-point scale)* (6) What did you learn from playing the game? *(open question)* (7) Do you have any recommendations for improving the game? *(open question)*

working on topics related to DRR, 6 out of 23 felt well-equipped to do so (rating their ability at least a 4 out of 5), while all other participants who work in the field of DRR rated it a 3 or less out of 5. During the post-game discussions, players' different expertise within the field of DRR appeared to be of less influence on the behaviour of the player. Among the main challenges in implementing and assessing DRR measures, participants reported a lack of contextual knowledge, including contingencies that influence DRR assessments and the long-term impacts of DRR measures, and a lack of available data and uncertainty.

As shown in Fig. 6a, in the post-game evaluation of the *Breaking the Silos* gameplay at UR2020, participants ($n = 20$) reported having enjoyed the game (an average of 4.3 out of 5 with no scores below a 3), they rated its representation of the complexities of real-life DRR decision-making as realistic (average of 3.7 out of 5), and participants rated both game immersion and increasing understanding of the complexities

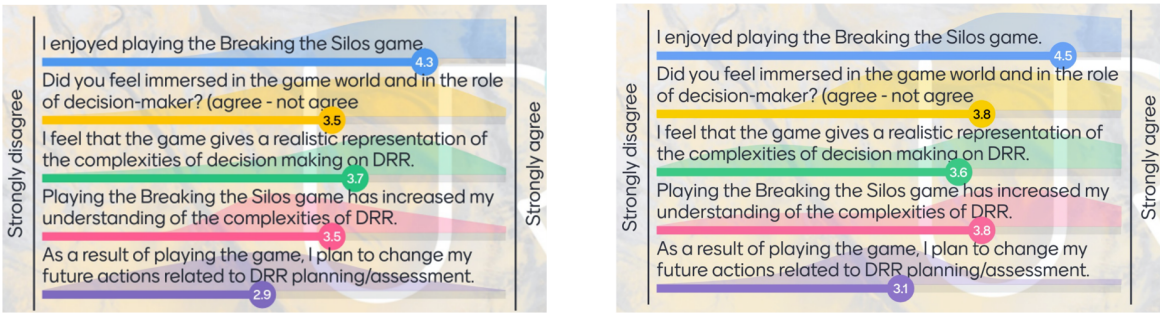

Figure 6. Replies to the post-game survey from the participants during UR2020 **(a)** and ETH **(b)**.

of DRM with an average score of 3.5. The feedback from the game played at ETH showed similar results (Fig. 6b): the 16 participants reported having enjoyed the game (an average of 4.5 out of 5 with no scores below a 4), and its representation of the complexities of real-life DRR decision-making was rated realistic (average of 3.8 out of 5).

However, when asked whether they plan to change future DRR actions, the average scores from the UR2020 and ETH participants is respectively 2.9 and 3.1, with a large spread across the UR2020 participants. When asked through an open question about the main lessons learnt, replies include learning about and reflecting on the "wealth of benefits and drawbacks" between DRR measures; the ongoing challenge in balancing risk of different hazards and between recovery and long-term preparedness; "the complex interplay between sectors (tourism, humanitarian, agriculture, etc.) and between short-term and long-term consequences of choices made". Despite the limited sample size, our preliminary findings support the calls from international organizations and platforms that there is a growing need for DRM researchers, practitioners, and decision makers to better understand the complexities of disaster risk. Finally, the participants were asked to reflect on the game itself and how it can be improved. Based on the feedback from the participants on the game's design, we will expand the available time. Others recommended to improve the visuals, e.g., by adding a 3D interface.

5 Concluding remarks and outlook

To the best of our knowledge, the growing need for multi-risk thinking is not reflected yet in serious games that help decision makers and practitioners become aware of the complexities of risk. *Breaking the Silos* is a role-playing game in which a team of eight key decision makers, experts, and stakeholders need to decide on the implementation of DRR measures after a disaster has hit their country. What sets *Breaking the Silos* apart from other disaster risk games is its explicit focus on multi-risk challenges that include different hazard types, intensities (and their interactions), different impact indicators, and (a)synergies between DRR measures. Moreover, the spread of expert knowledge between different participants and the high levels of freedom and randomness in the game design contribute to a realistic game.

By including different rounds that are each followed by a debriefing, the game encourages learning by doing. However, as is the case with all role-playing games, learning is dependent on the immersion and active participation of all players (Solinska-Nowak et al., 2018). By including an external moderator, the game organizer can have some influence on active participation by encouraging individual players and by coaching the president to take a role in motivating the team. Moreover, we noticed behavioural differences between the games played during UR2020 and at ETH. While at UR2020 most participants did not know each other, at ETH they knew the other participants very well. This created very different dynamics within each team. The participants of the games at UR2020 remained close to their role descriptions, especially the relationship aspect of their role with other roles. While at ETH, the solidarity between players was clearly visible and participants reported afterwards a clear sense of team spirit, which was not necessarily in line with the description of the relationships between the roles. When playing the game in the future, it can be considered to involve social scientists, specialized in participatory methods and behaviour, to further analyse the participants' gameplay and how behaviour changes over the course of the game through the learning-by-doing process.

While *Breaking the Silos* aims to reflect the complexity of risk and DRM, some simplifications were required. In the current game version, we selected three hazard types. However, this could be expanded either by adding different game versions or by adding more hazard types to the current game version. The game could also be tailored to specific training needs by, for example, increasing challenges of synergies between DRR measures. The online version of the game could be developed into a fully digital version, while the off-line version can be developed into a physical board game.

In post-game surveys during our two initial implementations of the game, participants indicated a growing need to

better understand the complexities of disaster risk. They also rated the game's representation of the complexities of DRM as realistic. These preliminary findings support the recent call from international organizations and platforms to move away from hazard-silo thinking. We therefore aim for the game to reach a large audience of DRM practitioners through risk conferences and training workshops, to support their abilities of working in an increasingly complex world.

Ethical statement. All participants of the UR2020 and the ETH games were older than 18 years. All feedback was collected anonymously using Mentimeter, and participation in the game and the pre- and post-game surveys was fully voluntary. Participants of UR2020 agreed with the session being recorded as part of their conference registration.

The ethics department of the Faculty of Science of the Vrije Universiteit Amsterdam states that if research conforms to the following code, further review by the ethics committee is not required:

- No harm is envisaged for the participants or the population from which participants have been drawn;
- Participants receive complete and accurate information about the goals of the research before they participate;
- Participants give active consent for participation in the research;
- Participants are not deceived without being thoroughly debriefed;
- Participants are healthy adults who are not in a vulnerable position;
- Personal and sensitive data are kept confidential and are stored in a secure environment.

Breaking the Silos, played during both instances (at UR2020 and ETH), complied with the code and therefore no ethical clearance was required.

Data availability. Please contact the authors when interested in playing this game or an adjusted version of the game.

Supplement. The supplement related to this article is available online at: https://doi.org/10.5194/gc-4-383-2021-supplement.

Author contributions. MCdR and AC conceptualized, designed, and developed the game with feedback from PJW. AC designed the MIRO environment with feedback from MCdR and PJW. MCdR prepared the article with contributions from all co-authors.

Competing interests. The authors declare that they have no conflict of interest.

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