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ADVANCED REVIEW

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Serious gaming in flood risk management

Steven Ashley Forrest[1,2] | **Martina Kubíková**[2] | **Jan Macháč**[2]

[1]Energy and Environment Institute, University of Hull, Hull, UK

[2]Institute for Economic and Environmental Policy, J. E. Purkyne University in Usti nad Labem, Czech Republic

Correspondence
Steven Ashley Forrest, Energy and Environment Institute, University of Hull, Hull, UK.
Email: s.a.forrest@hull.ac.uk

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Abstract

Serious gaming is increasingly used to explore important real-world problems and a growing number of serious games are addressing flood-related issues. However, there has been limited synthesis of these attempts and their contributions to the ongoing shift toward a more holistic and governance-based flood resilience perspective in flood risk management (FRM). This international review collates and analyses these attempts in order to develop a knowledge base of serious gaming in the field of FRM. It contains 37 games that were developed with different rationales that include engaging players in the topic of FRM, supporting practice by exploring future options through collaboration, improving communication of FRM, as educational tools, and to collect research data. The gameplay countries and player characteristics, game characteristics, relevance to FRM, game rationales, and collection of data are explored in this paper. Identified serious games provided an unconventional and entertaining approach to engage stakeholders on flood-related issues. The review analyzed the serious games in light of the shift toward flood resilience and identified limitations in the documentation of serious games and their potential in understanding the longer-term impacts of gameplay on players. Furthermore, the vast majority of reviewed games were played in a single country and missed out on understanding the cultural production and perspectives of FRM that could support cross-cultural learning and inspiration for future FRM strategies. Overall, the review identified an important role for serious games in the shift toward governance and the adoption of more holistic flood resilience perspectives.

This article is categorized under:

Human Water > Water Governance
Human Water > Methods
Science of Water > Water Extremes

KEYWORDS

flood resilience, flood risk management, serious games, systematic literature review

1 | INTRODUCTION

Flooding is increasingly recognized as an urgent societal issue that is predicted to worsen in the future. Disastrous flood events are expected to become more common due to factors such as sea-level rise, more frequent and intense heavy rainfall events, continued urbanization and urban growth, and inappropriate development (European Academies' Science Advisory Council, 2018; O'Donnell & Thorne, 2020; Winsemius et al., 2015). There is a growing recognition that not all flood events can be prevented and instead there is a shift toward an acceptance of some flooding (Forrest et al., 2020; McClymont et al., 2020). This acceptance, or "living with floods" perspective, places greater emphasis on reducing flood impacts as well as reducing flood risk (Liao, 2012). This change in emphasis necessitates a more holistic approach to flood risk management (FRM) that considers before, during and after the flood event with a greater focus on both preparation as well as bouncing forwards post-flood (Forrest et al., 2019).

This more holistic flood resilience approach has resulted in a wider range of stakeholders needing to be involved in FRM and greater attention being paid to the wider institutional context that influences FRM (Karrasch et al., 2021). Traditional FRM strategies, where the state is predominantly in control of FRM and building flood defenses, are moving toward "governance" approaches in many countries with a growing role for non-traditional FRM actors (Driessen et al., 2016; Meijerink & Dicke, 2008). These actors may not be specifically working on FRM projects, but they are increasingly needing to consider flooding and FRM in their own work and be aware of potential issues and concerns that could affect their own roles and responsibilities. Furthermore, the growing focus on going beyond "only" flood safety and attempting to derive multiple benefits and co-benefits from FRM projects contributes to an increasingly multi-disciplinary nature of managing floods, which has led to supporting and encouraging collaboration becoming a more prominent issue within FRM. For example, increasing attention is being paid to actors in upstream-downstream relationships (Machac et al., 2018) or FRM in relation to private property (Hartmann et al., 2019).

There is also a growing use of serious games in FRM. Serious games are becoming increasingly used to explore issues of sustainability, water resource management, climate change adaptation, environmental governance and management, urban planning, and disaster management in a highly engaging way (Aubert et al., 2018; den Haan & van der Voort, 2018; Medema et al., 2019; Savic et al., 2016; Solinska-Nowak et al., 2018). In comparison with "classical" board or party games, the aim of serious games is not primarily to provide entertainment, but for rationales such as learning, reflection, civic engagement, promoting behavior change as well as preparing players for future roles (Abt, 1970; Ampatzidou et al., 2018; Flood et al., 2018). Games have also been attributed to boosting public understanding and engagement relating to climate change and climate adaptation (Flood et al., 2018; Kwok, 2019). These "serious games" are carefully constructed environments in which "players" engage with content and attempt to achieve certain objectives or aims within the confines of set gameplay rules. Their value is becoming increasingly recognized in capacity development and increasing competencies for sustainable water management in Germany (Sewilam et al., 2017) as well as being included in disaster and flood-based educational curricula for school children in various countries, including the Netherlands and Brazil (Bosschaart et al., 2016; de Mendonca et al., 2019).

Despite the growing prominence of serious games, there are relatively few coordinated research agendas and actions in progressing the knowledge base of their use in FRM with many serious games being developed in isolation to one another. There is limited synthesis, review, and reflection of these games. Therefore, there is limited understanding of what is being done, who is being involved and how this connects to ongoing discussions in FRM. Previous reviews of serious games in other fields have helped to inform future game design and evaluation as well as to identify research opportunities (e.g. Aubert et al., 2018; den Haan & van der Voort, 2018; Flood et al., 2018; Medema et al., 2019). This paper aims to do the same to provide a better idea of how to go forwards in this exciting area of serious gaming in FRM.

This article focuses on reviewing serious gaming in FRM in order to explore how they can contribute to ongoing discussions concerning the shift to more holistic and governance-based flood resilience perspectives. The paper will introduce serious games and present the methodology used to identify and review academic literature on serious gaming in FRM. This review focuses on papers that include experiences of serious games and gameplay in FRM as opposed to papers that only describe a game and do not include evidence of gameplay experiences. The research findings will then be presented before a discussion of the potential benefits of serious gaming in FRM.

2 | SERIOUS GAMING

The definition of "game" is contested with no universal definition, although Salen and Zimmerman (2004, p. 83) understand them as environments wherein players "engage in an artificial conflict, defined by rules, that results in a quantifiable outcome." Serious gaming is also a broad topic that commonly identifies "serious games" as those that not only

provide entertainment value and enjoyment, but go beyond this and also have underlying objectives that are reached through gameplay. They are considered to be directed activities that have aims and objectives for players who need to make decisions within the context of set limitations (Abt, 1970). Serious games are not new and have existed in our societies as military drills, CBRNE emergency training scenarios, and strategic games designed to develop certain skills (e.g., chess). The topic has been approached from various perspectives with serious games being as simple as card games with die to being more complicated with virtual reality and computer simulations.

Serious games have recently been used in a wide range of fields from supporting cultural heritage (Anderson et al., 2010) and exploring the energy transition (Ampatzidou & Gugerell, 2018) to using prosthetic hands as part of medical rehabilitation (Kristoffersen, 2021). They have also been used to create "immersive environments" that can vary in their technology usage to be physical (e.g., board games), virtual (e.g., online interfaces), or a hybrid of both (Bellotti et al., 2010, p. 31; Aubert et al., 2018). Existing games, "Commercial Off The Shelf games" (Bellotti et al., 2010, p. 24), have also been used for creating stimulating educational experiences, for example, *Transport Tycoon* for "Mobility and Infrastructure Planning" courses and *Pandemic: Rising Tides* for "FRM" courses at the University of Groningen and University of Hull respectively. There is also a lot of excitement surrounding the potential use of serious games in order to facilitate social learning, test hypotheses, engage new audiences, encourage participatory approaches, increase risk perception and support communication, collaboratively solve problems, and foster changes in practices (Aubert et al., 2018; den Haan & van der Voort, 2018; Neset et al., 2020; Rodela et al., 2019; Solinska-Nowak et al., 2018). There are many potential benefits of serious gaming and this paper looks to identify how they can contribute to ongoing FRM discussions based on a review of existing academic research.

3 | METHODOLOGY

This systematic literature review aimed to identify experiences of serious games and gameplay linked to FRM. The emphasis was put on academic literature and research that had been presented in academic settings (e.g., conference papers) in order to present the current status of this topic in academia and to establish a foundation for future research. An important inclusion criterion was for the review to identify papers that incorporated "flooding" as a key component of the game. However, games that also incorporated multiple hazards (e.g., including drought) and wider management issues (e.g., climate adaptation planning) were included as long as flooding remained a key component.

A preferred reporting items for systematic reviews and meta-analyses-based approach was applied with the use of identification, screening and inclusion steps. The paper used two academic databases, Web of Science and Scopus, to identify relevant academic literature and research relating to experiences of serious games and gameplay within FRM. Several search terms were tested in Web of Science ("game AND flood": 363 results; "serious game AND flood": 43 results; "(game* OR gaming) AND flood": 403 results) and the following search terms were selected: "(game* OR gaming) AND flood*." These search terms yielded 455 results on Web of Science and 777 results on Scopus in March 2021. Subject area exclusion criteria were applied to remove results that were not relevant and belonged to subject areas such as "immunology," "medicine," and "nursing" leaving 49 and 73 results, respectively.

The titles and abstracts from the search results were manually skimmed and papers that focused on experiences of serious games and gameplay in FRM were selected. Initial search results included papers that were not relevant to this paper's aims and were excluded because they included the use of "game" as a situational description (e.g., the "blame game") or as a description of approach ("game theory"), evaluative models of flood risk, "game" mammals and their response to flooding, or as the paper was based on serious gaming in another field with flooding only included as background context (e.g., a focus on agricultural decision-making in areas near to rivers). Furthermore, initial search results that included "flood" in relation to "flooding attacks" in computing were manually removed. The option to remove similar results by excluding the subject area of "computing" was not taken as this may have excluded potentially relevant computer-based games related to flooding.

The two sets of search results were combined and duplicates were removed. An in-depth manual reading of the abstracts was then conducted to ensure that review items focused on details of gameplay experiences and results were excluded if they did not contain sufficient information on the game process, focused only on game designs that had not been played with participants, or focused on mathematical modeling as opposed to using real-life participants. These excluded search results hold value in supporting FRM-based serious gaming and modeling, however, this paper specifically focuses on experiences of serious games and actual gameplay relating to FRM.

Additional papers were suggested by relevant experts as well as being cited within an identified review item, these were reviewed and a further six review items were added to the analysis. Overall, a total of 38 relevant search results were identified and these were included in the main analysis (Figure 1). From the 38 papers identified, it became

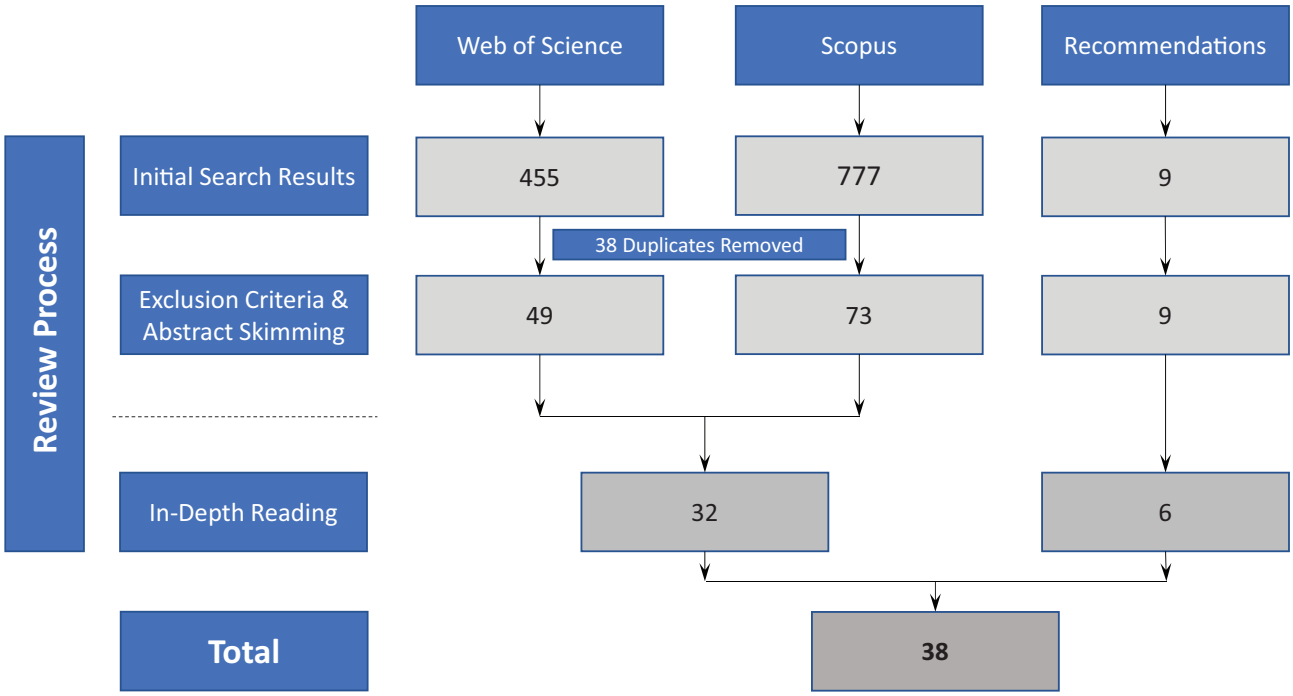

FIGURE 1 Systematic review process

evident that two papers referred to the same game. These have been included in the main analysis as they contained sufficient detail on gameplay, but care has been taken to analyze them together and avoid duplication of results. A full list of the 37 games included in the analysis can be found in Appendix.

The review focused primarily on peer-reviewed academic articles; however, it did identify instances of serious gaming on a flood-related topic that were published in conference papers and proceedings. Several conference papers identified were in short form and consisted mainly of a description of the game with only a small section on gameplay included. During the in-depth reading stage, these papers and proceedings were read and evaluated based on their quality and context with those detailing relevant insights into gameplay being included in the review.

The identified papers were then deductively analyzed based on game elements and categories that were identified as important from the initial literature review, which included: gameplay countries and player characteristics (i.e. who played the game), game characteristics (i.e. game format and user interface, and game location), relevance to FRM (i.e. inclusion of FRM approaches and relevant FRM stakeholders included), game rationales, and data collection from serious gaming. To improve the robustness of the analysis, two calibration points for the first 14 papers and then for 15 additional papers were included in the analysis process. At each calibration point, there were in-depth discussions and reflection on the analysis and coding by two of the authors. Changes in analysis and coding approach were discussed and then applied to future analysis as well as retrospectively to papers already coded. The remaining papers were coded based on this approach by one author.

4 | RESULTS OF GAME ANALYSIS

4.1 | Gameplay countries and player characteristics

The reviewed papers detailed games that had been played between 1974 and 2019 although the exact year of gameplay was not always stated in the papers. The games identified, and their gameplay experiences, in total have been played in 27 different countries. The reviewed games were played in countries in Europe (12 countries), Asia (8), North America (3), South America (2), Africa (2) and Oceania (1).

The reviewed games had been played at least once with the vast majority of the games being played in a single country either in one fixed location or in multiple locations within that country (Table 1). There were several games that were played in multiple countries as part of their design to encourage collaborations (e.g., *The Shariva Game*) or as they were played at international conference events (e.g., *The Willingness-to-Pay* game).

TABLE 1 Number of countries each individual game has been played in

Number of countries played in	Number of identified games
1	30
2	4
3	1
4	2

The games were rarely played with only one type of stakeholder and were often used to bring together a range of different perspectives. Players participating in the games included students (participated in 15 games), citizens (13), government organizations (12), academics (11), elected decision-makers (7), professionals in relevant fields (7), non-governmental organisations (NGOs) (4) and private organizations (3). Students included university students both studying FRM or a disaster-based subject as well as those with no previous experiences of water management (10) as well as elementary and high school students (4). Citizens included those who were specifically affected by the problem (9), such as farmers, residents and local community representatives, as well as including a general audience (5) identified through online recruitment, and in cafés (Gordon & Yiannakoulias, 2020; Yiannakoulias et al., 2020) and public events (Wendler & Shuttleworth, 2019). There were seven different games that involved "relevant professionals" who worked as technical experts, modelers, operational forecasters and hydrologists. Their affiliations were unclear and they could not be categorized as academics or government organizations. This was a result of a lack of player data being collected/recorded.

4.2 | Game characteristics

The reviewed papers included details of the game characteristics such as the format of the game and user interface. Games were developed to be played physically (10 of the games reviewed) using physical props, such as cards, tokens, physical game boards, and Lego. Conversely, eight games were developed to be played solely in a virtual environment, such as *SeCom 2.0*, *The Decision Game*, and *Project Lily Pad*. There were 19 hybrid games that incorporated both physical and virtual elements together. This hybrid format included the use of computer models for processing player choices and providing visualizations alongside physical boards, worksheets, and in-person (i.e., physical) team-based discussions. *Flooded* is a hybrid game that used Google Maps to show the player's live location on their mobile phone as players then physically walked/ran around their locality to fulfill quests. The most extensive hybridization approach was *The Virtual River*, which used a physical board game made of 143 hexagonal tiles representing elevation and land use. Players interact with and move the tiles on the board and these physical changes are captured digitally via a webcam. The data are processed through the game software and model interface, which projects the results back to the physical board for players to see. In physical, virtual and hybrid games, tokens were often used as a way to assign resources or "power" to players by giving them a set/finite resource that they then need to consider in their decision-making process, whether it is to try and spend the resource to undertake actions or to try and preserve their value (e.g., money tokens) to reach the game objectives.

The use of real-life or fictitious locations varied in the serious games reviewed. Real-life locations were used in 15 games reviewed and their use can raise awareness of flooding and potential FRM actions in a certain context as well as supporting the development of future plans and policies for those locations (Becu et al., 2017; Khoury et al., 2018). However, the use of real-life locations can be controversial when focusing on specific problems and lead to players adopting defensive positions or being wary of engaging in discussions. The use of fictitious locations can overcome this problem and was used in 19 of the games reviewed. For example, *The Shariva Game* used a fictitious river basin to avoid real-life sensitivities when discussing transboundary river basin issues in a game involving agency representatives from multiple countries. Fictitious games were often based on existing real-life examples with *MEGADAPT*'s fictional neighborhoods designed to reflect wider experiences in Mexico City, *Lords of the Valley* based upon a real-life situation in the Tisza River Valley of Hungary, and the *Waas Pilot* and *Sustainable Delta* games based upon typical river stretches found in the Netherlands. A further three games were situated within a national context of the country the game was being played in with limited detail on specific localities.

The games differed in their accessibility with the majority being made for particular clients/projects or for internal teaching and not publicly available. Several games were freely available online with the files for *Project Lily Pad*

TABLE 2 Overview of the inclusion of different flood risk management (FRM) measures relative to a flood emergency

FRM phase	Number of articles mentioning relevant action
Pre-flood	32
During the flood	7
Post-flood	1
Continuous changes	7

downloadable from a university website. Challenges exist in maintaining an online presence with the freely available *FloodSim* using Flash software that is no longer supported and is unplayable in many browsers (e.g., Google Chrome).

4.3 | Relevance to FRM

4.3.1 | Inclusion of FRM approaches

The review analyzed the FRM measures that were described and incorporated in the serious games (Table 2). An overwhelming majority of FRM measures focus on actions that can be taken in anticipation of a flood event (i.e. pre-flood) as opposed to actions during a flood event or in recovering from a flood event. Pre-flood measures included structural preventative measures (featuring in 16 games) whilst land management strategies and spatial measures ("pro-action") focusing on "living with water" were also popular in the games reviewed. Relatively few papers focused on measures that can be taken during a flood (e.g., emergency response or search and rescue), which is an important feature of flood resilience and the idea of "living with floods" in accepting that some floods will happen and that there needs to be greater attention on reducing flood impacts. Measures for after a flood event (e.g., post-flood relocation, training, or future planning based on flood event) were rarely discussed in the reviewed papers.

The review analyzed whether the game's goals guided players towards focusing only on flooding as a single issue or whether they are aligned with a more holistic perspective of FRM that incorporated other societal considerations. In games that focused on flooding as the only goal (15 games), the focus was on players providing flood protection whilst trying to spend the least amount of money or taking actions to minimize flood damages whilst still trying to maximize profits by reducing costs (Arnal et al., 2016; Bokhove et al., 2020; Khoury et al., 2018). The issue of flooding was framed as trying to get the highest level of safety whilst attempting to be as cost-effective as possible. There were additional games that focused on decision-making relating to forecasting or communicating warnings with flooding included as a key consequence.

Reviewed games incorporated issues relating to wider societal concerns in addition to flooding (18 games) relating to the environment, social aspects and happiness, water resources, financial health, agriculture, energy, political factors, and population growth. Games incorporated multiple objectives relating to this wider set of societal concerns that were dependent on the role that you undertook. For example, *The Floodplain Management Game* gave farmers the goal of creating prosperous farms, local authorities a role in relation to the welfare of farmers, and water managers an objective relating to water policy (Stefanska et al., 2011). Players were encouraged to consider these goals through the game objectives and mechanisms to determine player success in the games. For example, the *Cedar Rapids Multi-Hazards Tournament* included social, economic and environment issues as considerations for the final score, whilst *SPRITE* scored players' relative success in issues relating to population, environment and popularity as part of calculating their final score (Adam et al., 2016; Carson et al., 2018). In *LottoSim*, players had to prevent coastal flooding but could also create incentives for other players to pursue multiple goals, such as the "environmental friendly medal" or the "highest population increase award" (Becu et al., 2017). Furthermore, *SimBasin* gave players the objective of managing their river basin whilst trying not to incur penalty points for passing threshold values relating to flooding, agriculture, hydropower, river health, forest remaining, and wetland remaining (Craven et al., 2017).

4.3.2 | FRM stakeholders identified in games

The roles assumed by actors were analyzed in the review with players playing the role of FRM professionals, such as flood forecasters, flood protection officers, flood risk advisors or flood managers in many serious games. Further actors

included local government (e.g., councils and municipalities), policymakers and mayors (Taillandier & Adam, 2018; Tanwattana & Toyoda, 2018; Tsai, Chang, et al., 2015), water authorities and managers (Magnuszewski et al., 2018; Stefanska et al., 2011; Valkering et al., 2013), and first responders (Terti et al., 2019; Tomaszewski et al., 2020). In some cases, moderators took on roles such as central government (Magnuszewski et al., 2018), city managers (Nunnally et al., 1974) and actors such as mayors, journalists, lobbyists, buskers, and weathermen that then influenced the game conditions (Barends, 2001; Wendler & Shuttleworth, 2019). Furthermore, the growing role of citizens and civil society was recognized in the games with players acting as community leaders, volunteers or voluntary organizations, taxpayers, homeowners in flood-risk areas (Nunnally et al., 1974; Tanwattana & Toyoda, 2018; Tomaszewski et al., 2020), local environmental activists and farmers (Magnuszewski et al., 2018; Nunnally et al., 1974; Stefanska et al., 2011).

Players were not always assigned a specific role in the game and 12 games had players in their real-life role during the game as relevant stakeholders such as technical experts, decision-makers or farmers to provide input on a strategy (Carson et al., 2018; Souchère et al., 2010). Players also played the game in interdisciplinary teams where they brought in their own relevant experiences and knowledge (Carson et al., 2018).

4.4 | Identifying game rationales

The games were developed with the overall rationale of engaging players in the topic of FRM as well as to create curiosity and awareness of flooding (Ramos et al., 2013; Wendler & Shuttleworth, 2019). The reviewed papers highlighted the positive effects of using serious gaming approaches in FRM especially the interactive nature of gaming. Barends (2001. p. 2732) commented on the high levels of engagement that players had and how they committed to their game roles with one player remarking "How one gets influenced and enchanted by his specific interest during the course of the game! I am surprised." The gaming approach was identified as making the teams "fanatical" by Schelland et al. (2019, p. 671). The novelty of using games in FRM helped to reach new audiences and to engage them in the topic of FRM with the *SeCom2.0* evaluation finding that gameplay can be "very motivating" for players (Breuer et al., 2017, p. 5). However, Craven et al. (2017, p. 86) speculate that this novelty may not continue in subsequent games because it is down to "excitement over a new methodology."

Several games had additional rationales of supporting practice through exploring potential options and future pathways, supporting policy development and developing adaptive plans (Douven et al., 2014; Lawrence & Haasnoot, 2017; Valkering et al., 2013), as well as "anchor[ing] knowledge in the organisation" (Schelland et al., 2019, p. 667). The gameplay processes were often used to support practice by initiating dialogues between policymakers and scientists as well as between relevant stakeholders (Craven et al., 2017; Daré et al., 2018). Games incorporated negotiations, discussions, and collaboration elements as game dynamics to support the initiation of dialogues (Carson et al., 2018; den Haan et al., 2020; Douven et al., 2014; Souchère et al., 2010). Several reviewed papers connected the initiation of dialogues and collaboration in gameplay as supporting social learning and relationship building in FRM (Becu et al., 2017; Carson et al., 2018; Craven et al., 2017). Furthermore, the games allowed the testing of ideas, including providing the safety of being able to make mistakes, with only "large amounts of virtual damage" and without "real-world unintended consequences" (Breuer et al., 2017, p. 93; Gordon & Yiannakoulias, 2020, p. 10; Stefanska et al., 2011).

Games also aimed to improve existing communication approaches on FRM and to help communicate technical information to non-technical audiences (Bokhove et al., 2020; Craven et al., 2017; Khoury et al., 2018; Terti et al., 2019). This extended to raising flood awareness in communities (Arinta & Emanuel, 2020; Felicio et al., 2014; Lumbroso et al., 2008; Rebolledo-Mendez et al., 2009) and supporting communities' abilities to prepare for flooding through empowerment, promoting cooperation with local government, and through gameplay that explicitly aimed to build citizen capacity (Mannsverk et al., 2014; Tanwattana & Toyoda, 2018; Tomaszewski et al., 2020).

Games were used as educational tools to encourage active learning, raise students' levels of interest, and entertain participants whilst offering a learning experience (Barends, 2001; Tsai et al., 2020; Tsai, Wen, et al., 2015) and introducing the topic of FRM as well as water management and evacuation behaviors (Breuer et al., 2015; Felicio et al., 2014; Kitagawa et al., 2017; Nunnally et al., 1974; van Pelt et al., 2015). Games also focused on developing specific expertise such as spatial thinking and crisis response skills (De Kleermaeker et al., 2011; Tomaszewski et al., 2020).

Several games focused on collecting data on understanding decision-making by players, for example, on their willingness to pay for probabilistic flood forecasts for flood protection and to interact with scientific outputs (Arnal et al., 2016; Terti et al., 2019), to understand decision-making in uncertain conditions (Lawrence & Haasnoot, 2017; Lebel et al., 2016), as well as to understand decision-making for FRM at the household level (Gordon &

Yiannakoulias, 2020; Yiannakoulias et al., 2020). Games were also created with the rationale of collecting data from players' gameplay actions to validate existing theories and models developed by the researchers, including the value of using games to test hypotheses (Bokhove et al., 2020; Daré et al., 2018; Gordon & Yiannakoulias, 2020; Magnuszewski et al., 2018; Shelton et al., 2018).

4.5 | Collecting data from serious gaming

The reviewed games employed a range of different data collection approaches to identify their relative success that were related to before the game, during the game, immediately after the game, and a longer time period after playing the game (see Table 3).

Questionnaire-based approaches included specifically post-game evaluation questionnaires (used in 7 games) as well as questionnaires both before and immediately after the gameplay (10). These commonly aimed to establish a baseline of players' opinions and perspectives in the relevant areas before the game and then to ask the same or similar questions after the game in order to compare and identify any potentially game-driven changes. Two games used a before/after game questionnaire, but they extended the time period between gameplay and the second questionnaire to 1 month after gameplay (Taillandier & Adam, 2018) and 3 months after gameplay (Carson et al., 2018). Data were also collected after a longer time period after gameplay to identify longer-term impacts of gameplay with post-game interviews (Lebel et al., 2016; Rebolledo-Mendez et al., 2009) and emails asking for reflections (van Pelt et al., 2015).

Many of the reviewed games used in-game observations including a qualitative "thinking aloud" method whereby players were asked to verbally describe their thoughts and experiences during gameplay (Tomaszewski et al., 2020), the creative use of game characters (played by facilitators) to encourage in-game reflections of their experiences (Wendler & Shuttleworth, 2019), as well as recorded self-directed learning sessions (Tsai, Chang, et al., 2015). These observations were also captured by recording the player's computer screen, mouse tracks, voices and facial expressions (Tsai, Wen, et al., 2015) and another using GoPro cameras to record players' movements (Mannsverk et al., 2014).

Discussions and debriefing sessions immediately post-game were structured to focus on areas that were of particular interest to the game's aims, player development, and to further improve the game. These were considered important for games with learning aims that need sufficient organization to "facilitate learning, retention and reflection" (Mannsverk et al., 2014, p. 102). Players also had a role in self-assessment of the gameplay and their game experiences by completing post-game worksheets (Arnal et al., 2016) and a SWOT analysis (Douven et al., 2014). However, there was not always a fixed approach to data collection with one game having "instructors evolve their own evaluation systems" based on their gameplay experiences (Nunnally et al., 1974:25).

5 | THE POTENTIAL OF SERIOUS GAMING FOR FRM

The paper now discusses how serious gaming can contribute to ongoing discussions concerning the shift to more holistic and governance-based flood resilience perspectives as well as highlighting important issues for the further development of serious gaming for FRM.

TABLE 3 Forms of data collection used for serious games reviewed

Data collection approach	Number of identified games
Questionnaire-based	20
In-game observations	16
In-game decisions	5
In-game scores	4
Post-game discussions/debriefing sessions	16
Longer-term post-game follow-up	6

5.1 | FRM governance

The shift to governance within FRM and the broadening of the circle of actors involved was analyzed both in terms of the real-life roles and the game-based roles of players. A strength of serious gaming is that it can reach diverse audiences and encourage participatory approaches (Aubert et al., 2018; Solinska-Nowak et al., 2018). The review identified a broad range of real-life roles relating to students, citizens, government organizations, academics, elected decision-makers, professionals, NGOs, and private organizations. Their inclusion in the games enables a broader range of stakeholder involvement in issues of FRM and provides an opportunity for a wider range of perspectives on FRM to be brought into game discussions. The game-based roles available to players often went beyond traditional FRM actors and their inclusion into the game dynamics meant that players needed to acknowledge their perspectives and interests as well as what they can "bring to the table" for FRM. The use of serious games did bring people together and encouraged dialogues (e.g., *The Shariva Game*) as well as giving players an opportunity to play a different role and to understand the problem, perhaps one that they are very familiar with, from another perspective. One ongoing challenge in the shift towards governance relates to inclusion and reaching communities and citizens at-risk of flooding whose views may normally be excluded or potentially marginalized by traditional decision-making processes. The accessibility of serious games, including their virtual nature and the choice of gameplay location, could exacerbate this challenge by favoring those who are better connected both digitally and socially to be aware of these games and able to participate. Conversely, the assigning of game-based roles to potentially less powerful actors (including NGOs and community organizations) could make others more aware of their perspectives as well as "leveling the playing field" in terms of the differences in "power" between game players by giving them space to represent their views.

5.2 | Shift to flood resilience

Flood resilience can be understood as the "capacity of actors...to mitigate and prepare (pre-flood), to resist and respond (during the flood), before being able to recover from, adapt to, and transform after a flood event (post-flood)." (Forrest et al., 2019, p. 425). Flood resilience is a contested concept that has many definitions and perspectives that include bouncing back to the status quo post-flood, incremental post-flood adaptations to FRM, and larger-scale transformations of how flooding is perceived and managed (McClymont et al., 2020). The ongoing shift to flood resilience represents a more holistic approach to FRM that requires a greater diversity in approaches that includes more than traditional flood hazard control measures and incorporates social, spatial, and economic measures to reduce flood consequences. Several reviewed games entrenched the viewpoint that structural measures are the focus of FRM in the game options that they presented (i.e., flood-only games), while other games took a more holistic perspective that included a greater range of societal considerations in the decision-making process. The game dynamics in certain games worked to incentivize players to consider these environmental, social, and economic considerations at the same time as flood safety considerations. In this sense, the games supported the shift to flood resilience by incorporating multiple benefits and multiple goals into FRM discussions. The review identified a limited coverage of flood resilience opportunities over time with the majority of games focusing on pre-flood actions and very few considering during the flood (e.g., evacuation or response actions) and post-flood actions.

5.3 | Evaluating success for the player and success of the game

Evaluation is important to understand whether the game has been successful and to support the iterative development of the game. There was a tension between success for the player and success of the game with objectives and aims often focusing on only one of the two. There was also a limitation in data collection after the games in terms of the time that they covered and the amount of longer-term impact that games had (also identified as a problem with serious games relating to climate adaptation by Flood et al., 2018). The vast majority were limited to focusing on the immediate aftermath of gameplay and there were few that explored the longer-term impacts of gameplay. Therefore, it is uncertain as to how serious gaming can make sustained, longer-term contributions to FRM. This needs future gameplay experiences to be clearer about their objectives and aims as well as to follow-up with their participants to identify any long-term retention and impacts.

5.4 | Embedding of "the game": What happens outside of gameplay?

A common critique of community engagement in FRM is that it often only happens after a flood event has taken place and that engagement may be seen as a one-time thing without a clear, long-term strategy. The papers reviewed only provide a snapshot of the gameplay experience and all of the decisions and development are unlikely to be captured. Several games documented how they collaborated with others in developing the game, their efforts in embedding the game into wider systems, or of providing feedback to involved stakeholders post-game. However, there were limited discussions on the use of the games after they had been played and whether there would be targeted approaches to try to reach a wider audience. Future research could explore how to embed serious games in FRM within larger agendas or strategies that include engaging with prospective players in the development of the game and in the longer-term after playing the game. In doing so, it could improve the usefulness of gameplay for players as well as identifying how game elements can (or cannot) support longer-term changes.

5.5 | Cross-country learning

Games were sometimes deployed at international conferences and workshops that were able to bring together a wide range of perspectives from different FRM institutions and country-specific approaches. However, there was limited analysis and comparison between the approaches taken by participants from different countries. Furthermore, the games reviewed were predominantly played in a single country (see Table 1) and this misses out on the potential to reach wider audiences and the ability to examine differing cross-country perspectives to identify (potential) cross-cultural trends in FRM. Future research could compare different country-based understandings and approaches to FRM in order to understand the cultural production of FRM as well as to benefit from the opportunity to exchange knowledge between game creators and game players (i.e., from knowledge in the game and knowledge collected from gameplay). To reach a wider audience, there are opportunities to learn from the success of regular "commercial games" (e.g., the popular *Ticket to Ride* and *Pandemic: Rising Tides* games) wherein players can learn the game themselves and then self-facilitate successful gameplaying amongst their peer groups, friends and families. Achieving this wider reach and self-facilitation in FRM serious games would reduce barriers to playing the games in different countries and should be explored in the future with mechanisms to collect data on players' actions and choices. This would enable further cross-country comparison and potential learning through these serious games.

6 | CONCLUSIONS

The papers reviewed suggest that researchers and players have had positive gameplay experiences with serious gaming on flood-related issues. Serious games do have a role for supporting the shift to more holistic and governance-based flood resilience perspectives. Researchers noted that serious games can engage players in FRM issues as well as providing a safe, testing environment to experience flood conditions and make decisions on FRM options. Their benefits and opportunities include taking complex issues relating to FRM and creating environments in which players can explore them further. The review identified game rationales including collecting data to support FRM-related research, supporting communication and/or collaboration to improve existing practice and contribute to future policies, and in facilitating learning. The review into the potential contributions of serious gaming to FRM has led to the identification of three key messages and suggestions for future research into this area.

Firstly, the review has identified that serious games can provide benefits for engaging audiences in FRM. Serious games can be used as a creative way to engage with the broadening circle of stakeholders with an interest in FRM, but not necessarily focusing only on FRM. This can bring benefits for the ongoing FRM shift towards governance and more holistic flood resilience approaches. Several games were designed to make players consider the roles, responsibilities and interests of this wider range of actors who may not always be considered in traditional FRM, such as communities, citizens, NGOs and private businesses by including them as playable roles. Furthermore, in-game incentives were used to encourage consideration of social, environmental, and economic issues alongside FRM, which can support discussions focusing on the more holistic perspective of flood resilience. However, future serious game use in FRM should pay particular attention to who is "engaged" and which audiences are excluded due to accessibility issues relating to the game format or organization of gameplay.

Secondly, this review identified limited assessment of the long-term impact and embedding of the serious games. The games predominantly focused their analysis of success on reaching their rationales with multiple data collection approaches employed before, during and immediately after gameplay. However, the longer-term success and longevity of reaching game rationales was often unexplored, for example, the extent to which gameplay had influenced players' future decisions and choices relating to the topic. This also applies to the development of student, citizen and expert capacities in the gameplay where the longer-term retention of capacities was not subsequently explored. The long-term impact of serious games is connected to embedding them in wider aims and extends to negative player experiences and the potential for these to translate to future decisions made by players in their real-life roles. Future work in this field should investigate how to embed serious games into longer-term FRM agendas and strategies that also consider longer-term impacts.

These long-term impacts are difficult to assess as they are often not documented in the academic literature with Solinska-Nowak et al. (2018) having identified a related knowledge gap regarding the effectiveness of games in disaster risk management and Pereira et al. (2014) finding a limited ability to assess game impact into the longer term. This can be due to limited time for academics to publish and critically reflect on gameplay experiences in the academic literature. Therefore, greater importance should be given to providing space for discussions on the use of serious games in FRM and to recording (and reflecting on) short and longer-term gameplay experiences and impacts in the academic literature.

Thirdly, the reviewed serious games were predominantly played within one country context or if played with participants in an international setting there was no analysis of where the players had gained their experiences of FRM. It is known that countries have their own respective FRM approaches and that these are partially a product of their history of flooding amongst other cultural factors. We could speculate that this would therefore influence how individuals understand FRM and how they approach the issue of flooding. Serious gaming could provide an opportunity to explore how these differences manifest themselves across different countries and cultures by presenting the same problems to different groups and analyzing their responses. This cross-cultural approach could support the transfer of ideas, the spread of innovative solutions to FRM problems, and potentially provide inspiration for future FRM.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Steven Ashley Forrest: Conceptualization (lead); formal analysis (lead); investigation (supporting); methodology (lead); writing – original draft (lead). **Martina Kubíková:** Investigation (supporting); methodology (supporting). **Jan Macháč:** Conceptualization (equal); funding acquisition (lead); methodology (supporting); project administration (lead); writing – original draft (supporting).

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created in this study

ORCID

Steven Ashley Forrest https://orcid.org/0000-0001-5350-6441
Jan Macháč https://orcid.org/0000-0002-4037-7756

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