GeoHazards

MDPI

Article

Serious Games for Seismic Risk Education: The Case of the ENP-CP Project

Agostino Goretti [1] and Gemma Musacchio [2,*]

[1] Dipartimento della Protezione Civile, 00193 Roma, Italy; agostino.goretti@protezionecivile.it
[2] Istituto Nazionale di Geofisica e Vulcanologia, 20133 Milano, Italy
* Correspondence: gemma.musacchio@ingv.it

Abstract: This paper delves into the potential advantages of integrating gamification into seismic risk management education, with a specific emphasis on the efficacy of serious games in augmenting the learning process. It offers an illustration of gamification within the framework of a seismic risk preparedness project involving multiple countries, languages, and cultures and across the time of the COVID-19 pandemic. The innovation of this approach largely lies in shifting the focus from competition, which is typical in most games, to collaboration. Three digital serious games were implemented to tackle facets of seismic risk management that are particularly favourable for empowering communities at risk. These games were first used in a hybrid event where students from Algeria, Morocco, and Italy engaged in gameplay both in person within their respective classrooms and remotely with classes in each country. The evaluation study showed the positive impact of gamification in captivating young participants and thereby instilling best practices in seismic risk management.

Keywords: seismic risk reduction; seismic risk management; gamification; serious games; seismic risk education; seismic awareness raising

Citation: Goretti, A.; Musacchio, G. Serious Games for Seismic Risk Education: The Case of the ENP-CP Project. *GeoHazards* **2024**, *5*, 310–328. https://doi.org/10.3390/geohazards5020016

Academic Editor: Michalis Fragiadakis

Received: 30 January 2024
Revised: 21 March 2024
Accepted: 28 March 2024
Published: 8 April 2024

1. Introduction

Gamification is the integration of game elements into nongame contexts to engage, motivate, and educate users [1–4]. In recent years, there has been a growing interest in utilizing gamification in various fields, including disaster risk reduction (DRR) education [5]. The efficacy of disaster risk reduction is heavily contingent upon society's readiness and comprehension of risks [6–11]. Serious games [12–14] are designed with the primary purpose of conveying specific messages, teaching skills, or addressing important issues, rather than solely for entertainment. They play a pivotal role in the context of DRR, serving as effective instruments for conveying targeted messages while fostering comprehension and learning of critical issues [15–18].

One of the reasons serious games hold promise in DRR education is their alignment with effective learning processes, supported by the recent major shift from a traditional didactic model focused on instruction to a learner-centred model that emphasizes the active learner role and a learning-by-doing approach [9,19,20]. Engaging in gameplay inherently involves problem-solving activities, reasoning, memory retention, and teamwork—all of which are crucial elements of the learning experience [21]. By integrating these aspects into educational games, learners can better internalize and retain information related to disaster preparedness and risk management. The digital native young generation, who grew up surrounded by technology, finds digital serious games highly appealing. This attraction to technology-driven learning experiences can be harnessed to instil a culture of efficient disaster risk management in future societies.

Despite the potential benefits, integrating serious games into mainstream educational curricula remains a challenge [22,23].

Nevertheless, in recent years, the incorporation of serious games, rooted in the "learning by doing" philosophy, has been gaining significant popularity in science–technology–mathematics fields [3,20,22]. Factors such as limited awareness of their effectiveness, concerns about distraction, and a lack of integration into traditional teaching methods have hindered their widespread adoption in schools.

This might become a particularly significant missed opportunity for Disaster Risk Management (DRM) education, as younger generations not only represent the future of our communities but also serve as a bridge to reach and educate their families [5,8,23].

The early adoption of gamification in DRR focused primarily on the development of serious games. These educational games aimed to convey critical messages and impart disaster management skills to users in an interactive and immersive manner. For instance, *Disaster Master* (https://www.ready.gov/kids/games/data/dm-english/index.html; accessed on 2 April 2024) was designed as a simulation game, allowing players to respond to various disaster scenarios, make decisions, and witness the consequences of their actions. As technology continued to evolve, mobile applications emerged as powerful tools for gamified disaster risk reduction education. Applications like *Riskville* (https://www.kau.se/en/csr/collaboration/risklab/riskville; accessed on 2 April 2024) utilized geolocation and augmented reality features to engage users in real-world disaster scenarios. This app empowered individuals to explore potential hazards in their immediate environment, fostering a sense of preparedness and vigilance.

In recent years, gamification has undergone further transformation, integrating elements of social interaction, competition, and rewards [24–27]. Online platforms and social media have been harnessed to create collaborative and competitive environments. One notable example of the evolution of gamification in DRR is the *Disaster Hero* platform (https://games4sustainability.org/gamepedia/disaster-hero/; accessed on 2 April 2024). Initially a serious game, *Disaster Hero* has evolved into an interactive platform that enables users to connect with their peers, share knowledge, and collectively work towards improving disaster resilience in their communities. Another innovative application is *DRR Quest*, a mobile AR game that transforms disaster-prone areas into virtual quests. Users engage in scavenger hunts, collecting virtual resources to build their disaster preparedness toolkit. This interactive experience not only imparts essential knowledge but also fosters a sense of empowerment and self-efficacy among players.

To maximize the impact of gamification in disaster risk reduction education, collaboration among various stakeholders is essential. Governments, educational institutions, game developers, and disaster management experts must work together to design and implement effective serious games tailored to specific educational objectives.

In this paper we describe the making of three digital serious games designed to engage youths in a collaborative approach to seismic (DRM). They were implemented within a European-funded project for civil protection under the European Neighbouring Policies. After describing the project and the serious games, the lessons learned in using the games in an international student environment are discussed.

2. The Background Framework

The serious games described in this paper were implemented within the framework of the EU-funded European Neighbourhood Policy—Civil Protection Pproject (ENP-CP; https://www.facebook.com/ENPCPproject/; accessed on 2 April 2024). The project was a preparedness action of the Union Civil Protection Mechanism (UCPM) to strengthen disaster risk management capabilities and support the development of operational civil protection capacities in Algeria, the Kingdom of Morocco, and Tunisia. It lasted three years, starting in 2020 and ending in 2023.

Work Package 4 (WP4) was aimed to strengthen awareness-raising initiatives and educational campaigns on seismic risk in Algeria and Morocco. It leveraged existing structures, capacities, and initiatives within the countries, not only transferring best practices but also

enhancing existing initiatives by collaboratively developing new materials and innovative models for DRR education in a multistakeholder approach.

The project encountered challenges because of the COVID-19 pandemic, which imposed significant limitations on travel. Consequently, most of the activities originally planned for in-person implementation were carried out remotely. Despite these obstacles, WP4 managed to turn adversity into opportunity by devising specific hybrid and interactive formats to maintain participants' engagement.

In addition to organising e-workshops accompanied by 14 dissemination videos available in Italian, French, and English showcasing Italian best practices on seismic risk awareness and education campaigns, WP4 facilitated livestreaming in French of the hybrid "National Live I Don't Risk, 2021 Edition". Furthermore, it developed a web-based platform for storing and sharing information on initiatives and resources used in the campaigns. WP4 also conceptualized and created three serious digital games alongside coordinating educational events involving schools from Italy, Algeria, and Morocco. This initiative was a collaborative effort among various stakeholders, including national civil protection authorities, research centres, school teachers, game developers, and national and local educational institutions, in the three countries. This collective approach aimed to maximize the impact of gamification in disaster risk reduction education. For a more comprehensive overview of WP4 activities, refer to [28].

3. Materials and Method

The games were designed with the intention of conveying specific messages while promoting learning and understanding of the essential issues of seismic DRM.

Given that the target audience comprised students 12–14 years old, video games were chosen for their heightened capacity to engage users.

The games were embedded into a fil rouge of civil protection activities encompassing the entire DRM cycle, starting from understanding the phenomenon and progressing through prevention and preparedness measures that both students and citizens could implement.

A triad of digital games was developed (Figure 1):

- *Catch the Plate—Digital* focuses on understanding the phenomenon and the seismic exposure by providing information on earthquake locations and urban areas.
- *Make Your Room Safer* deals with prevention by outlining best practices to mitigate seismic risk associated with non-structural components of buildings.
- *The Emergency Bag* emphasizes preparedness, highlighting the importance of having necessary tools for evacuation and demonstrating the situations where they are essential.

The games were designed by the authors and implemented by BerGAME (https://www.bergame.eu/bergame.html; accessed on 2 April 2024) in multiple languages (Italian and French) and can be executed in single- and dual-player mode. The languages are those of the countries that made use of the games within the ENP-CP project.

In the dual-player mode, two remote players simultaneously view the same environment on their screens via a web application, with the option for each player to select their preferred language. Players take turns solving problems and making decisions to achieve a common goal.

This mode of engagement enables the overcoming of spatial limitations, fosters a cooperative approach between players, and facilitates a more effective dissemination of the key messages embedded within the games.

The primary objective of the games is to reinforce knowledge rather than test it. Typically, a short yet fully interactive seminar or introduction suffices to impart the necessary insights for playing the games effectively.

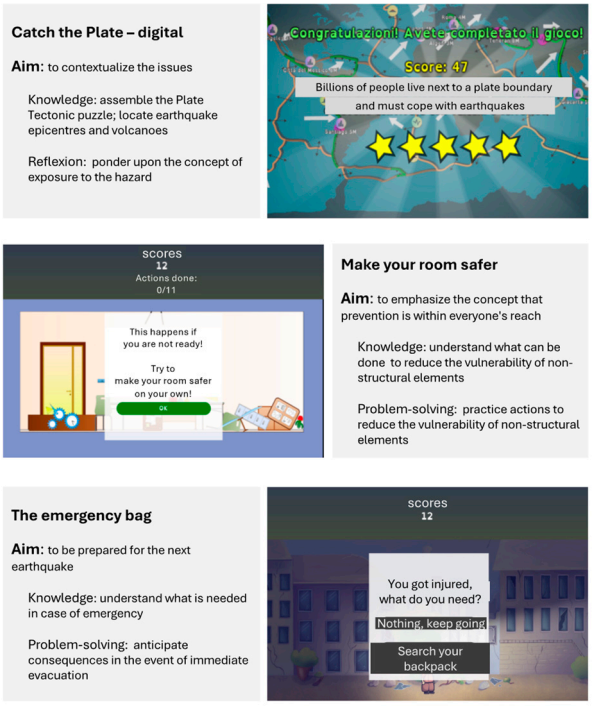

Figure 1. An infographic of the games.

3.1. Catch the Plate—Digital

Catch the Plate—Digital is a digital serious game designed to introduce players to seismic risk management issues, making it the ideal starting point within the triad of games. The primary goal of the game is to emphasize the correlation between the plate boundary's locations, earthquake occurrence, and proximity to densely populated areas. Its focus lies in examining risk by looking at hazard and exposure. The gameplay primarily revolves around problem-solving activities, memory retention, and teamwork principles. The underlying message of the game is conveyed through its opening and closing statements (Table 1), encouraging players not to underestimate the consequences of living near a plate boundary.

Table 1. Messages of the game *Catch the Plate—Digital*.

***Catch the Plate—Digital* Textual Key Messages**	
Opening statement	Earthquakes do not happen everywhere. If you live next to a plate boundary, you will not be able to avoid earthquakes.
Closing statement	Billions of people live next to a plate boundary and must cope with earthquakes.

The game has a duration of approximately 20–30 min and is divided into three sequential sections, predominantly featuring drag-and-drop actions (Figure 2). Scoring is based on a reward system rather than penalization. The game is summarized through the infographic shown in Figure 2.

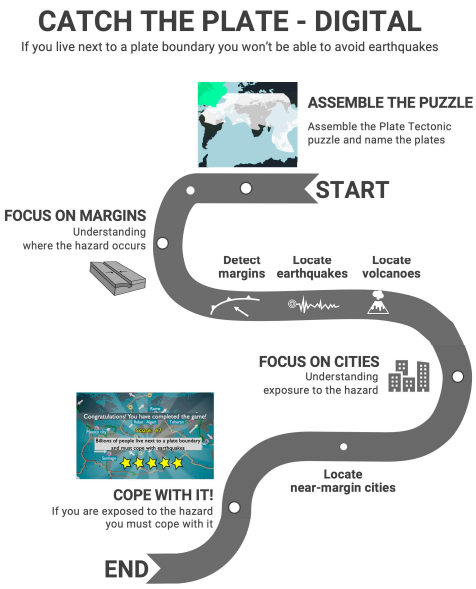

Figure 2. Infographic of the game *Catch the Plate—Digital*.

The first two sections aim to impart general knowledge about plate tectonics and the hazards occurring at plate boundaries. Players are tasked with (i) assembling a puzzle made of tectonic plates and labelling them, and (ii) identifying plate boundaries while locating earthquake epicentres and volcanoes. The third section prompts players to consider exposure by challenging them to position several major cities on the plate tectonic map. The final map displays the tectonic plates and their boundaries, along with the locations of earthquakes and volcanoes and selected major cities worldwide. Additionally, due to its development within the ENP-CP project framework, and following inclusivity principles, the capital cities of Italy, Algeria, and Morocco are featured regardless of their risk.

Before initiating the game during outreach events, a brief seminar was conducted to introduce the game and emphasize the non-random distribution of earthquakes on Earth. This seminar also introduced the concept of risk, focusing on the exposure of populations residing along or near plate boundaries.

The game draws inspiration from the activity "The Plate Tectonic Puzzle" [29,30], where children collaborate in teams to position small tokens representing volcanoes and earthquake epicentres on a previously assembled wooden jigsaw puzzle of tectonic plate pieces. The activity was later adapted into a carboard game called "Catch the Plate" [30] where the assembly of the jigsaw puzzle is followed by quizzes related to specific earthquakes and volcanoes, engaging players in small teams. Both the activity and the cardboard game primarily offer phenomenon-oriented information. By addressing exposure, *Catch the Plate—Digital* transforms the game into a more suitable tool for seismic DRM purposes.

3.2. Make Your Room Safer

Make Your Room Safer is a digital serious game addressing seismic prevention to reduce the vulnerability of a building's contents. It was designed with the primary objective of educating players, by suggesting actions and envisaging their consequences, on preventative best practices that non-experts can perform and at the same time highlighting when the assistance of an expert is necessary. The actions within the game are based on four keywords: move–protect–secure–retrofit. These keywords were introduced in a practical guide to reduce the vulnerability of non-structural elements addressing citizens and students [31,32]. The guide was developed as part of the KnowRISK (Know your city, Reduce seISmic risK through non-structural elements) EU-funded project [31]. For instance, the "move" action involves relocating furniture and heavy, fragile, or unstable objects to lower shelves and away from exits. "Protect" addresses valuables, electronic equipment, and glass objects, while "secure" is required for tall or heavy furniture, wall-mounted

or suspended cabinets, hanging fans, and lamps. The "retrofit" action pertains to gas, plumbing, and electrical systems, false ceilings, windows, and plaster, which should be addressed by specific experts, such as seismic engineers.

The game incorporates problem-solving activities, reasoning, memory retention, and teamwork. It enables players to take actions and to evaluate their consequences. Through the presentation of earthquake consequences with and without preventive measures in typical environments such as a bedroom and a classroom, players can easily learn how to improve their safety. The underlying message of the game is that when living in a seismic area, you may need to implement actions to make your environment safer. This message is conveyed through the opening statements (Table 2) of the game.

Table 2. Messages of the game *Make Your Room Safer*.

***Make Your Room Safer* Textual Key Messages**	
Opening statement	Earthquakes cannot be avoided, but damage? Yes! If you live in a seismic area, how would you make your house safer?
Other statement	Move, protect, secure, and retrofit are actions that have increasing costs and need increasing abilities.
Closing statement	Move, protect, or secure items that could fall.

The game has a duration of approximately 20–30 min and is divided into two sequential sections, primarily featuring drag-and-drop actions (Figure 3). Scoring is based on a reward system rather than penalization. The game is summarized through the infographic shown in Figure 4.

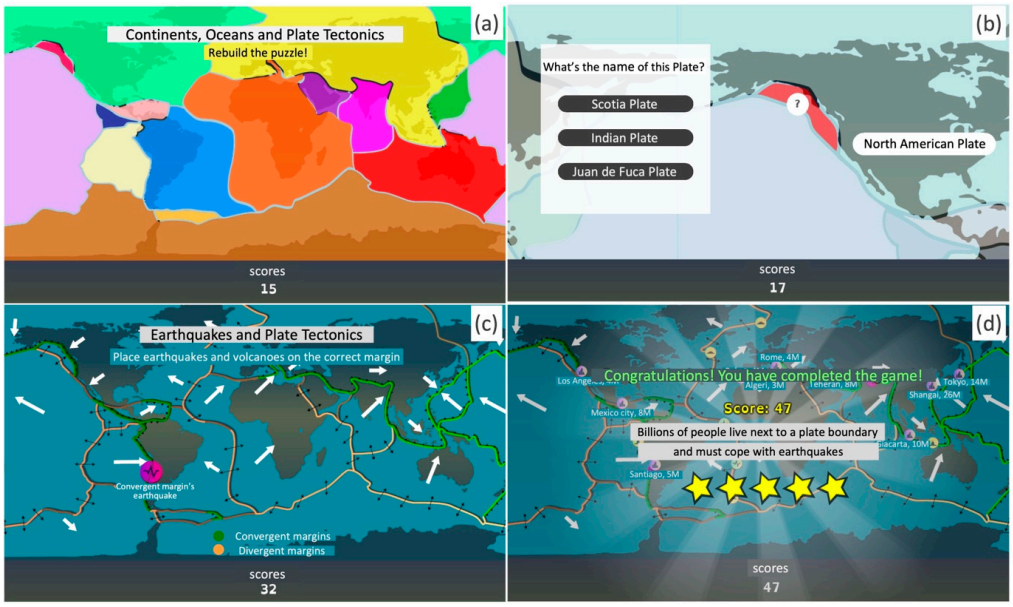

Figure 3. Screenshots of *Catch the Plate—Digital* serious game in the single-player mode showing the plate tectonic puzzle (**a**), the labelling of the plates (**b**), the locating of earthquake and volcanoes based on plate boundaries (**c**), and the placing of some major cities worldwide (**d**). White arrows show the velocity of the plates; black arrows and triangles depict divergent and convergent boundaries, respectively. The text in English shown in the figure is edited and superimposed on the French/Italian text.

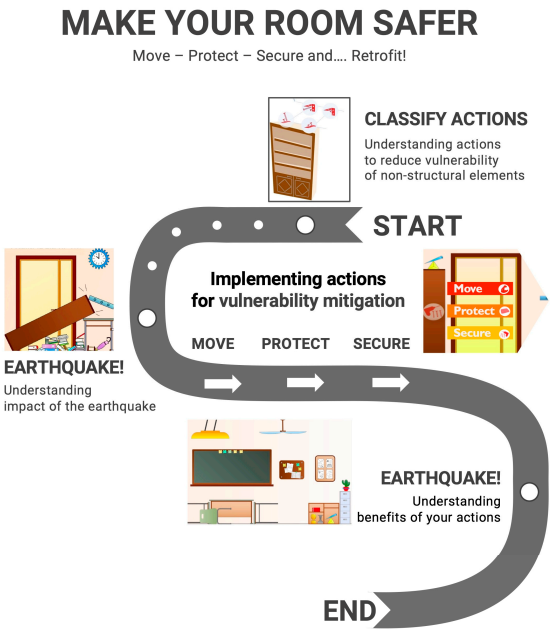

Figure 4. Infographic of the game *Make Your Room Safer*.

The first section aims to impart general knowledge on prevention measures using the four keywords move–protect–secure–retrofit (Figures 4 and 5). This section primarily relies on problem-solving and memory retention principles. Players must correctly categorize cards depicting building contents into the four actions, move, protect, secure, and retrofit, that can be used to reduce non-structural elements' seismic vulnerability. Icons displaying the appropriate tools and anchorage elements for each action are provided on the screen. Vulnerabilities are identified on the card by a red "X" on the card, while suggested solutions to mitigate vulnerabilities are marked by a red "V."

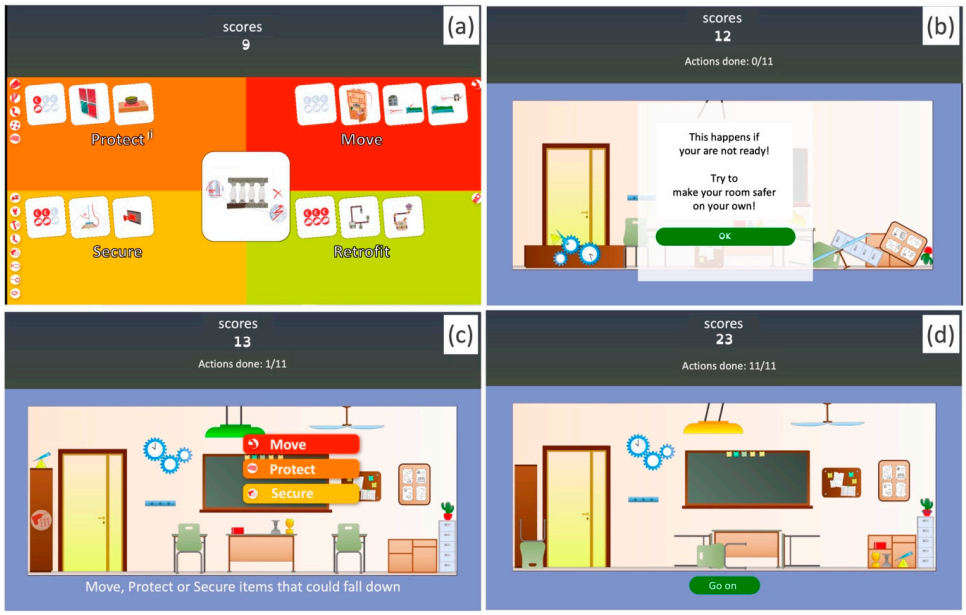

Figure 5. Screenshots of *Make Your Room Safer* serious game in the single-player mode. Cards showing building content are categorized based on measures to reduce the content vulnerability (**a**); earthquake damage to non-structural elements before any preventive action is taken (**b**); selection of the measures to reduce the vulnerability of the non-structural components (**c**); and effectiveness of the implemented measures (**d**). The text in English shown in the figure is edited and superimposed on the French/Italian text.

The second section of the game focuses on prevention in actions through drag-and-drop interactions and animations. This section primarily centres on decision making and assessing the consequences of these decisions. An animation shows the impact of the earthquake on the non-structural components of a classroom or bedroom before any preventive action is taken. Players are then tasked with implementing measures to reduce the vulnerability of these components by selecting actions associated with the move–protect–secure keywords. The retrofit keyword is excluded as it typically requires the intervention of an expert rather than being implemented by citizens. A second animation readily shows the effectiveness of the players' choices by showing the possible earthquake damage in the new configuration. Forces applied to the objects are calculated based on preselected ground motion. When in dual-player mode, each player takes turns implementing actions, fostering a collaborative approach.

Before initiating the game during outreach events, a brief seminar explained the differences between structural and non-structural building components as well as the potential damages by earthquakes.

The game draws inspiration from the two cardboard games "Do it Right: Be Safer!" and "Find the Difference: Be Safer!" [32].

3.3. The Emergency Bag

The Emergency Bag is a digital serious game designed with the primary objective of educating players on seismic preparedness. The game challenges players on "What do I need in case of emergency?", providing suggestions of tools needed in case of immediate evacuation, asking players to make decisions and respond to various disaster scenarios, and envisaging consequences of the player choices.

The underlying message of the game is conveyed through its opening, serving as an encouragement to be prepared (Table 3) and a reminder of the importance of readiness in the face of earthquakes.

Table 3. Messages of the game *The Emergency Bag*.

***The Emergency Bag* Textual Key Messages**	
Opening statement	Get ready for the earthquake! There are items that could save your life. Which are they? How many of them can you put in a small backpack?
Other statement	The needed items in case of emergency.
Closing statement	Remember: being ready can make the difference.

The game has a duration of approximately 20–30 min and is divided into two sections to be played sequentially. These sections primarily involve drag-and-drop actions and decision making (Figure 4). Scoring is based on a reward system rather than penalization. The game is summarized through the infographic shown in Figure 6.

The game is structured in two sections. In the first section, players are tasked with selecting the tools they believe would be necessary in the event of an emergency from those displayed on the screen. They must then fill a small backpack with their chosen items. In the second section, players assess the appropriateness of their choices through a storyline where a child faces typical situations that might arise immediately following an earthquake (Figure 7).

Figure 6. Infographic of the game *The Emergency Bag*.

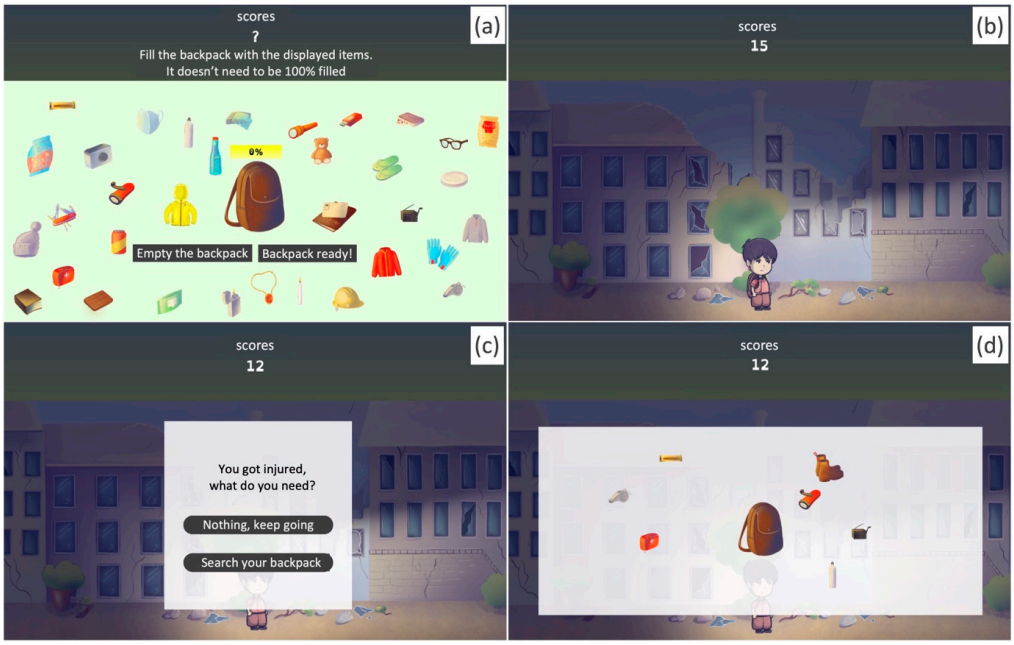

Figure 7. Screenshots of *The Emergency Bag* serious game in the single-player mode showing the tools that can be chosen to fill the backpack (**a**). Each tool is accompanied by a percentage indicating the volume it occupies in the bag as well as the available space remaining. A child is depicted facing typical post-disaster situations where key items are needed. The child walking at night in the postdisaster's environment (**b**); an injured post-disaster situation (**c**); selection of the tool from those available in the bag to address a post-disaster situation (**d**). The text in English shown in the figure is edited and superimposed on the French/Italian text.

At the conclusion of the game, a list of major needs and the related tools to address them is presented to the players (Table 4). It serves as a reflection on the adequacy of their choices and provides additional guidance on essential tools for emergency preparedness.

Table 4. List of common basic needs in case of emergency displayed in the game *The Emergency Bag*.

Common Basic Needs in Case of Emergency
1. To attract rescuers' attention.
2. To walk around safely.
3. To drink and eat.
4. To treat wounds.
5. To deal with cold, hot, or rainy weather conditions.
6. To access information about the situation.
7. To take care of personal hygiene.
8. To have a multitool to be used in various situations.
9. To have personal documents for identification and communication.

The tools to be included in the backpack are selected by the player from a long list of items that could potentially be useful, useless, or even dangerous in post-disaster situations. This variety prompts players to engage in reasoning and critical thinking. The selected tools must fit into a small backpack that everyone should have ready in case of evacuation. Players are encouraged to imagine the potential scenarios after an earthquake and consider what might be needed for immediate evacuation, while also considering the limited space in the backpack.

Even in the single-player mode, if played in small teams, the game can stimulate discussions because some tools have multiple uses. The game is not intended to provide definitive answers or solutions but rather to anticipate difficulties that might arise after a disaster and encourage preparedness. In the dual-player mode, one tool per player is selected in turns to fill the bag, fostering a collaborative approach, and scenes are played alternately.

The post-disaster situations presented in the game are designed to highlight key needs, such as wearing appropriate footwear for walking on debris; having a functioning flashlight; having a first aid kit to treat wounds; carrying water and energy-giving and non-perishable food; and having a whistle to attract rescuers' attention.

While the game does not need an introductory seminar, during outreach events, presenting a typical post-disaster situation can help participants envision possible needs, enhance their understanding of disaster preparedness.

The game draws inspiration from the *Treme–Treme* [20,32,33] game and the "What should I do and what should I take with me in the case of an earthquake?" educational activity [29].

3.4. Interactivity of the Games

The interactivity of the games relies on player agency, game mechanics, feedback systems, and social interaction.

The three games all have a high player agency, as players have a significant amount of freedom and autonomy in shaping the game world and its events through their decisions. In the game *Catch the Plate—Digital,* players can select where to locate earthquakes, volcanoes, and cities. In the game *Make Your Room Safer,* player can select the objects to be fixed or moved. In the game *The Emergency Bag*, players can select the objects to be included in the backpack.

Game mechanics govern the actions players can take, the constraints they must operate within, and the outcomes of their decisions. In the game *The Emergency Bag*, movements are restricted according to the situation and players' choices, and resource management is most evident. The scoring system is always included in the games.

Feedback systems, helping players understand the consequences of their actions and make informed decisions, are also included in the games. For example, in *The Emergency Bag* game, feedback is received when using wrong tools; in the *Make Your Room Safer* game, objects fall as the result of an earthquake if they are not fixed.

Social interaction is one of the main objectives of our games. Social interactivity is fostered through player-to-player interactions, mainly as cooperation. In *The Emergency Bag* game, the selection of the objects to be included in the backpack is performed by the two players in turn. Therefore, the possibility to progress through the scenes depends on the choices of both players. Similarly, in the *Make Your Room Safer* game, the selection of objects to be moved, fixed, or secured is performed by the two players in turn. All the games in dual-payer mode follow the 3-chance rule: 3 wrong actions and it is the other player's turn.

3.5. The Educational Strategies

In developing serious games for educational purposes, several strategies were employed to ensure effectiveness and engagement. Learning objective alignment was the main adopted strategy: all three games focus on teaching relevant concepts, skills, and knowledge that are part of the same educational goal: risk management is a full decision-making process. We also incorporated an active learning strategy into a collaborative and social learning strategy. Students are engaged in hands-on and interactive experiences, such as building a digital puzzle in the game *Catch the Plate—Digital* or in a simulation of possible, yet real, situations, as in the games *Make Your Room Safer* and *The Emergency Bag*. The collaborative and social learning strategy was the ground upon which the exchange of civil protection best practices stood. We allowed students to work together, share ideas, and collaborate during the gaming sessions, both within each classroom and across classrooms. This was achieved by including a dual-player mode that allowed each class group to cooperate using gameplay mechanics to reach the common goal in a win–win approach. This in turn reinforced the general message of risk management.

The real-world relevance was another adopted learning strategy. *Make Your Room Safer* and *The Emergency Bag* display familiar scenarios, where the event occur and actions are taken, illustrating how the skills learned during the game are applicable in real-life situations.

3.6. Accessibility and Inclusivity Aspects

To make the games applicable to a diverse student population required considering accessibility and inclusivity aspects. While accessibility was not specifically addressed in the games, inclusivity was incorporated through cultural representation, gender and identity, and language accessibility.

For instance, in *The Emergency Bag*, some tools were removed from the long list of objects to be included in the backpack because they were considered not appropriate to the climate or cultural conditions of Algeria and Morocco. Stereotypes, biases, and gender identity were avoided in the hero of the game *The Emergency Bag*, who is a child not showing any specific gender. In the game *Catch the Plate—Digital*, among other worldwide cities in seismic-prone areas, reference is also made to the capitals of Italy, Algeria, and Morocco, without distinction of their different risk levels. As for language accessibility, as already mentioned, each player, when playing games in dual mode, can select the preferred language between French and Italian.

3.7. Technological Aspects of the Games

To provide a perspective on the practicalities and scalability of the educational tools developed, technological aspects of the games are briefly elucidated. The games were crafted using the Game Maker development platform. The end products were video games specifically tailored for installation on desktop computers operating on the Windows platform. These games were equipped to support both single-player and dual-player modes. To enable dual-player functionality, a server-side game management system was integrated.

In terms of communication protocol, a custom TCP-based system was implemented. This system streamlined the management of multiple concurrent games within a single

server-side application, ensuring smooth operation and effective coordination between players.

However, the actual implementation of the dual-mode play does not permit more than two players simultaneously. The initiation of the game by a third player would result in a game crash. Due to this limitation, the games cannot be freely released in their current configuration.

4. Implemented Learning Activities Using Serious Games

The three described serious games were incorporated into various learning activities, starting from the hybrid event conducted during the ENP-CP project, spanning three days in the fall of 2022.

On the first day, Italian students and Algerian students engaged in interactive sessions both in person within their respective classes and remotely between classes via an IT communication setup. Practical activities, including the serious games, were conducted, with Italian and Algerian experts introducing and facilitating these activities. The second day mirrored the format of the first day, with Italian students interacting with Moroccan students. Simultaneous interpretation was provided on both days, and materials used in practical activities were prepared with Italian and French text for accessibility (slides or paper sheets). On the third day, two classes of Italian students interacted. In total, six classes comprising 108 students participated, with each class consisting of 20–26 students aged between 12 and 14 years.

During these events, the classes played the serious games in a two-player mode, sharing the same screen and alternating actions according to predefined shifting rules. To ensure all the students could visualize the game and observe class behaviour, each class was equipped with two digital large screens. The first screen was connected to the laptop running the games, while the second one projected the view of a camera located in the other class via a Zoom meeting. The same Zoom meeting facilitated interpretation services as well.

The same three games were subsequently featured in science outreach events, such as ScienzAperta ("Open Science") in April 2023 (https://ingvterremoti.com/2023/05/31/scienzaperta-scuole-2023-presso-la-sezione-di-milano-dellingv/; accessed on 2 April 2024) and the Week of Planet Earth in October 2023 (https://www.mi.ingv.it/index.php/it/didattica-e-divulgazione/news/114-la-settimana-del-pianeta-terra-presso-la-sezione-ingv-di-milano; accessed on 2 April 2024), at the National Institute of Geophysics and Volcanology, and in schools in the frame of the educational activities that the authors usually carry out. They were used in single-player mode with a common discussion at the end of the gaming section. These additional experiences are not addressed in this paper.

5. Discussion and Lessons Learned

To evaluate the effectiveness of serious games in learning activities, the perspectives of both students and teachers were assessed through questionnaires distributed immediately after the ENP-CP project event (See Supplementary Materials). These questionnaires were translated into Italian, Arabic, and French to accommodate the diverse linguistic backgrounds of the participants.

Two sets of questionnaires were distributed: one for students and another for teachers, aiming to gather feedback from both groups. The questionnaires comprised both qualitative and quantitative assessments. Qualitative feedback was gathered through open-ended questions, while quantitative feedback was collected using a five-level Likert scale.

In addition to assessing the delivery of messages to students, our primary focus was on determining the reception of the collaborative approach employed in the games by both students and teachers. This aspect is crucial for supporting the use of these games in international exchanges of best practices related to DRM.

It should be considered in the following discussion that Algeria did not return the completed questionnaires.

5.1. Results from the Questionnaire for the Students

The questionnaire for students was composed of 16 questions, among which 5 are open questions aimed at understanding what students liked most and what they learned. The questions are grouped as follows:

- Experience of educational activities and drills at school.
- General questions on scoring the games students played during the event, the type of game they like (alone or group games; competitive or collaborative; on paper or computer), and the event (the short seminar before each game; the language barrier).
- What they learned, through an open question for each game.
- What the objectives of the games were.
- What they liked the most and the least, through open questions.
- If they would come back to play with us.

Analysis of the questionnaires reveals several noteworthy findings. Firstly, most students (70%) had no prior experience with risk education activities, and a significant portion (54%) had not participated in earthquake drills at their schools (Figure 8). Regarding preferences for gaming, students showed a preference for playing games in small groups (43%) or as a whole class (41%). Most students expressed a preference for computer games (52%), while a considerable number (45%) enjoyed both computer and paper games. Notably, a substantial majority of students (60%) expressed a preference for collaborative games, indicating a positive response to the event.

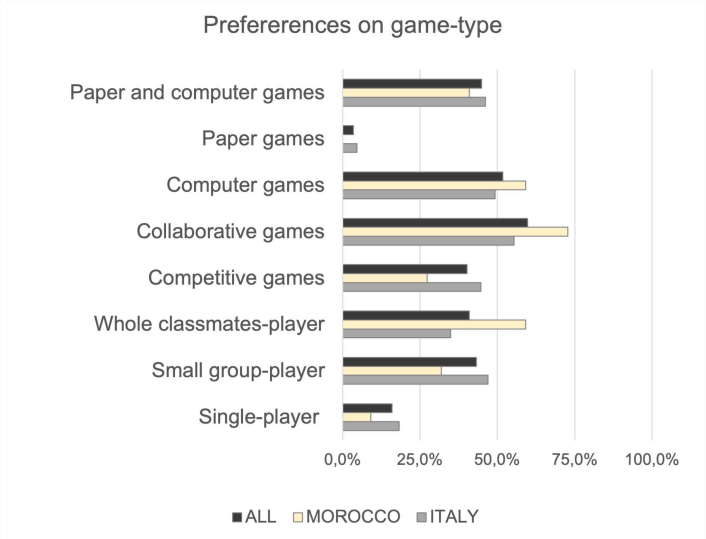

Figure 8. Students' answers on whether they like group games and computer, paper, collaborative, or competitive games. The breakdown of percentages (Morocco, Italy, and whole sample) is shown.

Interestingly, when comparing data from the two countries, Moroccan students showed a greater appreciation for the collaborative aspect compared to Italian students. Despite this difference, more than 90,5% of the students from both countries expressed a desire to repeat the experience.

Almost all the students (92%) found useful the short seminar delivered before each game. While students expressed overall satisfaction with all the games, *The Emergency Bag* received the highest scores in both countries, as seen in Figure 9, which shows the average preference of the students for the three games in a five-level Likert scale [34] with the value of 1 matching less and 5 matching a lot.

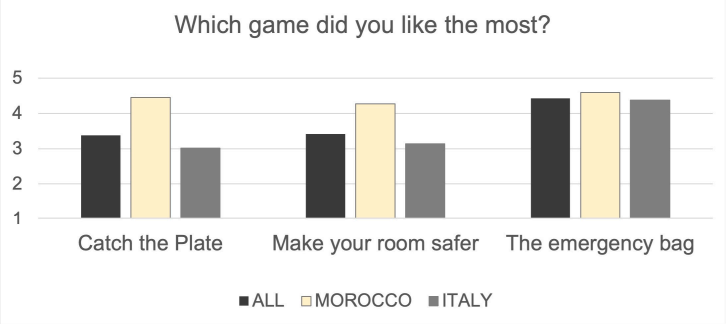

Figure 9. Students' answers to the question "Which game did you like the most?" The *Y* axis plots the average preference of the students in a 5-level Likert scale [34], with 1 matching less and 5 matching a lot. The breakdown of preferences (Morocco, Italy, and whole sample) is shown. The title displays the question asked to the students.

To evaluate students' comprehension of the primary messages conveyed by the serious games, we addressed students with the following open-ended question: "What did you learn?" The answers were grouped into three categories intended to be related to the game messages, preparedness, prevention, and earthquake occurrence, delineated by the phrases "how to be prepared," "how to reduce damage," and "where the earthquakes occur." Subsequently, we charted the occurrence of the answers falling in the relevant category for each game (Figure 10). The illustration indicates that, overall, students understood the intended message for each game. However, notably, *The Emergency Bag* game demonstrated the highest effectiveness, with 95% of correct responses.

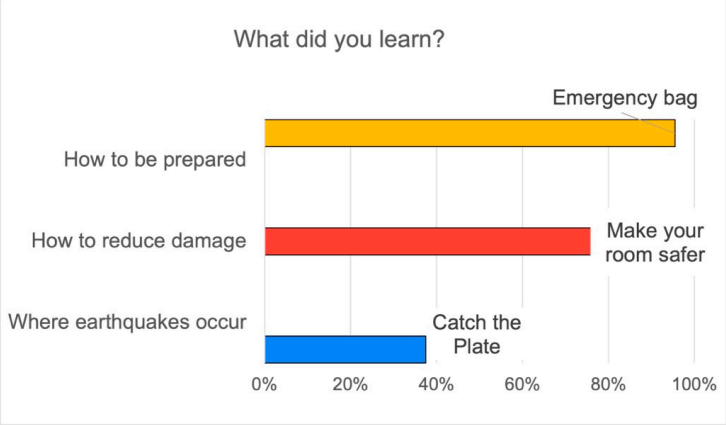

Figure 10. Students' answers to "What did you learn?" The diagram plots the frequency of the answers falling in the relevant category for each game. The title displays the question asked to the students.

To gain a deeper understanding of whether the students grasped the intended message, the open-ended question "What did you learn?" was followed by a multiple-choice question focusing on the objectives of each game. It should be noted that the same set of answers, i.e., the same set of objectives, was adopted for each game.

Answers again indicate that students successfully understood the intended messages conveyed by the games and that *The Emergency Bag*, the most effective game, better aligns with the intended learning objectives.

The analysis also revealed that the concept most challenging for students to grasp is related to "hazard exposure and risk" and the need to cope with earthquakes. This difficulty may stem from the fact that these concepts and this message may be perceived as more "theoretical" than the ones related to "damage prevention" or "preparedness" (Figure 11).

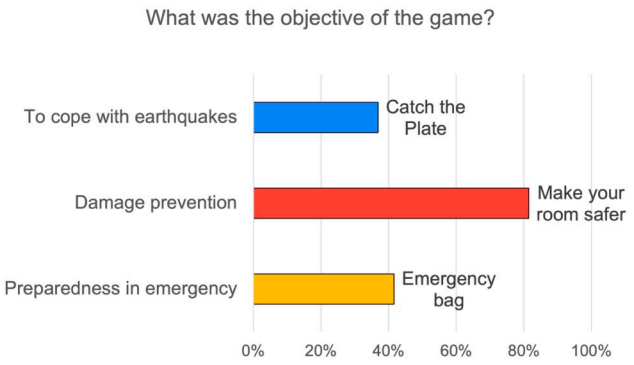

Figure 11. Students' answers to the directive "Pick the objective of each game". The title displays the question asked to the students.

It is worth reporting the impressions of the students, showing their engagement in the activities, as a result of the qualitative assessment. The following answers were recorded to the question "What did you like the most?": "I liked it all", "Everything that happened throughout the morning", "Sharing with students from another country", "How to react to a disaster", "To get the information through the games", "The games and the idea to take a lesson with Algerian/Moroccan students to understand a new language and new students", "Play with the students from Algeria. We have played a game with boys from another country who didn't even spoke our language and I felt anyway engaged", "Speak with peers from Algeria and play with them", "Have a lesson not in the usual way but through games", "I liked the games a lot and the team work", "The explanation about the earthquakes and The emergency bag", "I liked everything, but I liked playing the games the most", "When they explained us the structural elements and they challenged us with the games", "The emergency bag that make you understand how to get prepared in case of an earthquake", "To play with boys form other countries and languages and to discover that we are all members of the civil protection".

5.2. Results from the Questionnaire for the Teachers

The questionnaire for the teachers is composed of 18 questions, including 6 open-ended questions.

Teachers' answers confirmed that students were highly engaged in the activities. Teachers viewed the event as an excellent opportunity to teach topics in a more engaging manner.

Overall, teachers provided positive feedback and found the short introduction before each game to be beneficial. Addressing in the same event the phenomenon, prevention, and preparedness was considered to be able to provide a more holistic understanding of DRM. Additionally, the emphasis on collaboration rather than competition was well received by the teachers.

We asked the teachers to rate each game on six attributes: (1) effective, (2) useful to develop citizenship skills, (3) interesting, (4) educational, (5) useful for teaching, and (6) interactive. All the games received positive ratings across all attributes. However, *Catch the Plate* received the highest scores for usefulness for teaching and skill development, while *Make Your Room Safer* was rated highly interactive. *The Emergency Bag* received high ratings across all six attributes.

To assess teachers' overall satisfaction, we calculated the average scores for each game across the six attributes. The analysis revealed that teachers' perspectives were generally aligned with those of the students (compare Figures 9 and 12). However, teachers showed a greater preference for *Catch the Plate*.

Figure 12. Teachers' answers to "Rate the game attribute". The *Y* axis plots the average teacher appreciation of the games on a 1-to-5 Likert scale [34], with 1 matching less and 5 matching a lot, based on the following 6 attributes: (1) effective, (2) useful to develop citizenship skills, (3) interesting, (4) educational, (5) useful for teaching, and (6) interactive.

It is worth also reporting the impressions of the teachers, showing their point of view about the activities, through the qualitative assessment. The following answers were recorded to the question "What was the added value?": "The students learned a lot about natural disasters and are going to share it with their colleagues as part of the awareness campaign", "This is the game where they learned the most new knowledge, as they were supervised by civil protection personnel from both countries", "The exchange and experience of a different reality", "The format and the switching from work in small groups to whole classroom engagement", "The idea of collaboration instead of competition".

6. Conclusions

We used gamification as a tool for seismic DRM education targeting students 12–14 years old.

Within a work package of the EU-funded European Neighbourhood Policy—Civil Protection project (ENP-CP; https://www.facebook.com/ENPCPproject/; accessed on 2 April 2014), dedicated to strengthening seismic risk awareness-raising initiatives and educational campaigns in Algeria and Morocco, three digital serious games were developed. The games were tailored to address several aspects of seismic risk management (knowledge, prevention, and preparedness). In the games, players engages in problem-solving activities, reasoning, memory retention, and response to various disaster scenarios. In the games, they also make decisions and witness the consequences of their actions in a teamwork environment. A key innovation in our gamification approach was the adoption of a collaborative, rather than competitive, ethos, emphasizing the efficacy of collaboration in DRM. Due to limitations in the current configuration, such as the dual-player mode allowing only two players at a time and not any two players at a time, the games are not yet released to the public.

The games were used in a pilot initiative aimed at establishing new models to strengthen cross-country risk management practices and later in other national initiatives, involving approximately 650 students in total within a year. The effectiveness of the serious games in educational activities was evaluated through post-activity questionnaires. Analysis of the collected data revealed the significant potential of gamification in developing life skills and fostering resilient, risk-prepared communities.

The learning strategy regarding DRM understanding and actions, emphasizing self-protection, contributes to fostering effective and enduring behavioural change for seismic risk. It clearly outlines what individuals can do when facing risks and when it becomes necessary to seek expert assistance. Indeed, the games were developed to rely on the following mechanisms to induce lasting behavioural changes: (i) learning objective alignment, as all three games focus on teaching relevant concepts, skills, and knowledge that are part of the same educational goal: risk management is a full decision-making process; (ii) real-world relevance, as the games display familiar scenarios illustrating how the skills learned in the game are applicable in real-life situations; and (iii) feedback systems, as players understand the consequences of their actions and make informed decisions. The above mechanisms, jointly with the social interaction and active learning strategy, facilitate the learning of key

messages on seismic prevention and preparedness. Students can then play a pivotal role as ambassadors for the key messages to their parents. By sharing insights gained from their educational experiences, students can serve as influential advocates for positive change, empowering their parents to become actively engaged in supporting the key messages.

The postevent assessment showed that the main messages of the games were comprehensively understood by the students, providing the basis for the mentioned behavioural changes. It is also acknowledged that behavioural changes can happen only if the principles shaping future behaviours largely lie within the school system. It would be ideal, then, to deliver in the future an educational package and to have the games integrated into curricular activities. This was beyond the scope of the ENP-CP project and could be the scope of future projects. It is worth mentioning that because of the activity's success, representatives from the Ministry of Education of Morocco, who attended the event, expressed interest in capitalizing on this pilot initiative and implementing similar programs in various regions of Morocco. Additionally, the Regional Educational Academy of Morocco showed interest in expanding this initiative to other provinces, potentially integrating it into the formal education curriculum.

The limitations of this study mainly stem from the nature of the pilot study and pertain to the limited number of students engaged in international activities, or in two-player mode, and to the limited diversity in school grades. In addition to this, the use of interpreters limited direct interaction between schools and may have led to misunderstandings or misinterpretations. The feedback questionnaire deserves improvements, based on the lessons learned, and a more structured use across events where the games are used. Overcoming these limitations provides clear directions for future research, together with the possibility to expand to other risks, such as floods and forest fires, include additional countries, and address accessibility and cultural representation in more detail.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/geohazards5020016/s1.

Author Contributions: The authors share equal contribution to all the phases of the work and of the drafting of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: The project Preparedness action for European Neighbourhood Policy countries—Civil Protection Project (ENP-CP) is funded by the European Union under grant ECHO/SUB/2019/B1/816936.

Data Availability Statement: Due to privacy and confidentiality as well as restrictions imposed by agreements with participants, we are unable to share the dataset used in this research.

Acknowledgments: The project Preparedness action for European Neighbourhood Policy countries—Civil Protection Project (ENP-CP) is funded by the European Union under grant ECHO/SUB/2019/B1/816936. The views and opinions expressed here are entirely those of the authors and do not reflect the official opinion of the European Commission. We thank the students, professors, and directors of schools participating to the international event: G.B. Monteggia Primary Grade School (Laveno Mombello, Varese- Italy), Les Aurès High School (El Biar, Alger, Algeria), and Amrou Alem High School (Rabat, Morocco). Special thanks to the General Directorate of Civil Protection of Algeria and the General Directorate of Civil Protection of Morocco, partners of the ENPCP project. We thank Maria Giovanna Sestito, Silvia Zidarich, Elisa Ferrari, Sara Lovati and Fabio Varchetta from INGV for their support in testing the games during science outreach events at the Milano Division of INGV. We thank the three anonymous referees for the interesting and valuable comments and suggestions that significantly improved the overall quality of the paper.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Deterding, S.; Dixon, D.; Khaled, R.; Nacke, L. From game design elements to gamefulness: Defining "gamification". In Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, Tampere, Finland, 28–30 September 2011; AcademicMindTrek 2015. Association for Computing Machinery: New York, NY, USA, 2011; pp. 9–15. [CrossRef]
2. López-Belmonte, J.; Segura-Robles, A.; Fuentes-Cabrera, A.; Parra-González, M.E. Evaluating Activation and Absence of Negative Effect: Gamification and Escape Rooms for Learning. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2224. [CrossRef] [PubMed]
3. Veldkamp, A.; van de Grint, L.; Knippels, M.C.P.J.; van Joolingen, W.R. Escape education: A systematic review on escape rooms in education. *Educ. Res. Rev.* **2020**, *31*, 100364. [CrossRef]
4. Veldkamp, A.; Knippels, M.C.P.J.; van Joolingen, W.R. Beyond the Early Adopters: Escape Rooms in Science Education. *Front. Educ.* **2021**, *6*, 622860. [CrossRef]
5. Musacchio, G.; Saraò, A.; Falsaperla, S.; Scolobig, A. A scoping review of seismic risk communication in Europe. *Front. Earth Sci.* **2023**, *11*, 1155576. [CrossRef]
6. Appleby-Arnold, S.; Brockdorff, N.; Callus, C. Developing a "culture of disaster preparedness": The citizens' view. *Int. J. Disaster Risk Reduct.* **2021**, *56*, 102133. [CrossRef]
7. Coombs, W.T.; Holladay, S.J. *The Handbook of Crisis Communication*; Wiley-Blackwell: Hoboken, NJ, USA, 2012; 768p, ISBN 978-1-444-35651-9.
8. Fernandez, G.; Shaw, R. Youth Council Participation in Disaster Risk Reduction in Infanta and Makati, Philippines: A Policy Review. *Int. J. Disaster Risk Sci.* **2013**, *4*, 126–136. [CrossRef]
9. Torpan, S.; Hansson, S.; Rhinard, M.; Kazemekaityte, A.; Jukarainen, P.; Meyer, S.F.; Schieffelers, A.; Lovasz, G.; Orru, K. Handling false information in emergency management: A cross-national comparative study of European practices. *Int. J. Disaster Risk Red.* **2021**, *57*, 102151. [CrossRef]
10. Wendling, C.; Radisch, J.; Jacobzone, S. *The Use of Social Media in Risk and Crisis Communication*; OECD Publishing: Paris, France, 2013. [CrossRef]
11. Katsikopoulos, P.V. Individual and community resilience in natural disaster risks and pandemics (COVID-19): Risk and crisis communication. *Mind Soc.* **2021**, *20*, 113–118. [CrossRef]
12. Wilkinson, P. A Brief History of Serious Games. In *Entertainment Computing and Serious Games. Lecture Notes in Computer Science*; Dörner, R., Göbel, S., Kickmeier-Rust, M., Masuch, M., Zweig, K., Eds.; Springer: Cham, Switzerland, 2016; Volume 9970. [CrossRef]
13. Rushby, N. Editorial: Making serious games better. *Br. J. Educ. Technol.* **2012**, *43*, 179. [CrossRef]
14. Vaz de Carvalho, C.; González González, C.S.; Popescu, E.; Rugelj, J. Editorial: Serious games—Volume II. *Front. Comput. Sci.* **2022**, *4*, 1088284. [CrossRef]
15. Crepaldi, M.; Colombo, V.; Mottura, S.; Baldassini, D.; Sacco, M.; Cancer, A.; Antonietti, A. The Use of a Serious Game to Assess Inhibition Mechanisms in Children. *Front. Comput. Sci.* **2020**, *2*, 34. [CrossRef]
16. Hawthorn, S.; Jesus, R.; Baptista, M.A. A review of digital serious games for tsunami risk communication. *Int. J. Serious Games* **2021**, *8*, 21–47. [CrossRef]
17. Fleming, K.; Abad, J.; Booth, L.; Schueller, L.; Baills, A.; Scolobig, A.; Petrovic, B.; Zuccaro, G.; Leone, M.F. The use of serious games in engaging stakeholders for disaster risk reduction, management and climate change adaption information elicitation. *Int. J. Disaster Risk Reduct.* **2020**, *49*, 101669. [CrossRef]
18. Madani, K.; Pierce, T.W.; Mirchi, A. Serious games on environmental management. *Sustain. Cities Soc.* **2017**, *29*, 1–11. [CrossRef]
19. Garris, R.; Ahlers, R.; Driskell, J.E. Games, motivation, and learning: A research and practice model. *Simul. Gaming* **2012**, *43*, 587–606.
20. Lathwesen, C.; Belova, N. Escape Rooms in STEM Teaching and Learning—Prospective Field or Declining Trend? A Literature Review. *Educ. Sci.* **2021**, *11*, 308. [CrossRef]
21. Solinska-Nowak, A.; Magnuszewski, P.; Curl, M.; French, A.; Keating, A.; Mochizuki, J.; Liu, W.; Mechler, R.; Kulakowska, M.; Jarzabek, L. An overview of serious games for disaster risk management—Prospects and limitations for informing actions to arrest increasing risk. *Int. J. Disaster Risk Reduct.* **2018**, *31*, 1013–1029. [CrossRef]
22. Fotaris, P.; Mastoras, T. Escape Rooms for Learning: A Systematic Review. In Proceedings of the 13th International Conference on Game Based Learning, ECGBL, Odense, Denmark, 3–4 October 2019; Academic Conferences and Publishing International Limited: Reading, UK, 2019; pp. 235–243. [CrossRef]
23. Mitchell, T.; Haynes, K.; Hall, N.; Choong, W.; Oven, K. The Roles of Children and Youth in Communicating Disaster Risk. *Child. Youth Environ.* **2008**, *18*, 254–279. [CrossRef]
24. de Carvalho, C.V.; Coelho, A. Game-Based Learning, Gamification in Education and Serious Games. *Computers* **2022**, *11*, 36. [CrossRef]
25. Caserman, P.; Hoffmann, K.; Müller, P.; Schaub, M.; Straßburg, K.; Wiemeyer, J.; Bruder, R.; Göbel, S. Quality Criteria for Serious Games: Serious Part, Game Part, and Balance. *JMIR Serious Games* **2020**, *8*, e19037. [CrossRef]
26. Breien, F.S.; Wasson, B. Narrative categorization in digital game-based learning: Engagement; motivation & learning. *Br. J. Edu. Technol.* **2020**, *52*, 91–111. [CrossRef]

27. Kirriemuir, J.; Mcfarlane, A. Literature Review in Games and Learning. In *Futurelab Hal-00190453*; Futurelab: Bristol, UK, 2004. Available online: https://telearn.archives-ouvertes.fr/hal-00190453 (accessed on 2 April 2024).
28. Goretti, A.; Musacchio, G. Strengthening Risk Awareness and Educational Campaigns within the EU funded ENP-CP project. In Proceedings of the 2nd International Conference on Urban Risks Conference, Lisbon, Portugal, 23–25 June 2022; Available online: https://hdl.handle.net/2122/15777 (accessed on 2 April 2024).
29. Musacchio, G.; Piangiamore, G.L.; D'Addezio, G.; Solarino, S.; Eva, E. "Scientist as a game": Learning geoscience via competitive activities. *Ann. Geophs.* **2015**, *58*, S0328. [CrossRef]
30. Misiti, V.; Musacchio, G. Catch the Plate (Acchiappa la Placca). 2019. Available online: https://www.ingv.it/comunicazione-e-divulgazione/educational/gioco-acchiappa-la-placca (accessed on 6 August 2023).
31. KnowRISK. Know Your City, Reduce seISmic Risk through Non-Structural Elements. European Commission's Humanitarian Aid and Civil Protection Grant Agreement ECHO/SUB/2015/718655/PREV2. 2017. Available online: www.knowriskproject.com (accessed on 2 April 2024).
32. Solarino, S.; Musacchio, G.; Ferreira, M.A.; Elena, E. Playing games for risk prevention: Design, implementation and testing of serious games in recent European projects UPStrat-MAFA and KnowRISK. *Ann. Geophys.* **2021**, *64*, SE327. [CrossRef]
33. Botellho, D.N.G. Treme-Treme 2.0—A Serious Game to Teach Children Earthquake Preparedness. Master's Thesis, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal, 2019.
34. Likert, B. A technique for the measurement of attitudes. *Arch. Psycology* **1932**, *140*, 55.