https://doi.org/10.5194/egusphere-2026-4049
Preprint. Discussion started: 1 September 2026

Heroes of Disaster: a semi-cooperative board game for training pre-service primary teachers in disaster risk reduction

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Abstract. Disaster risk reduction (DRR) education is increasingly recognised as a core competence for schools, yet initial teacher education often offers limited opportunities to rehearse actionable preparedness decisions. This study presents the design and educational rationale of *Heroes of Disaster*, a serious semi-cooperative board game developed to support scenario-based DRR learning, and reports on its classroom implementation and exploratory evaluation with pre-service primary teachers. The evaluation addressed three research questions concerning changes in protective-action judgements and self-reported preparedness behaviours; changes in DRR-related self-perceptions and risk awareness; and participants' appraisal of the game as a cooperative, classroom-oriented learning resource. Using a pre-test and delayed post-test design, with the post-test administered two weeks after gameplay, we collected data through structured questionnaires partly adapted from prior serious game instruments and framed around future teachers' role as mediators of school–community preparedness. The instruments were designed to capture DRR-related judgements in typical risk situations, self-perceptions of DRR-related skills and risk awareness, and post-intervention appraisals of the game (e.g. clarity, motivation, realism, cooperation, and classroom usefulness). In the matched sample, composite pre-test/post-test analyses showed a significant improvement in protective-action judgements and self-reported preparedness behaviours, whereas general DRR-related self-perceptions and risk awareness showed only a small, non-significant descriptive increase. Participants also reported a positive appraisal of the learning experience, particularly regarding the game's perceived contribution to DRR learning, real-life applicability, cooperative dynamics, and motivational value. Overall, these findings support the educational potential of *Heroes of Disaster* as a teaching resource for moving from fragmented, hazard-centred instruction towards community-oriented DRR literacy through interactive and participatory learning dynamics.

1 Introduction

Over recent decades, the frequency and impacts of natural hazards have increased in many regions of the world, driven by the combined effects of climate change, land-use change, and the growing exposure of populations and infrastructures (IPCC, 2022; UNDRR, 2019; Cutter et al., 2015). Floods, heatwaves, wildfires, earthquakes, and coastal hazards produce not only direct losses, but also long-term disruptions in livelihoods, health, and education systems, with mounting evidence of learning losses and school disruption under weather extremes (Venegas Marin et al., 2024; Pal et al., 2023). In this context, the Sendai

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Framework for Disaster Risk Reduction 2015–2030 explicitly highlights the need to strengthen risk awareness, preparedness, and public participation through education, communication, and local strategies (UNDRR, 2015). Community-based disaster risk management (CBDRM) approaches emphasise the active role of at-risk populations in identifying, analysing, and managing disaster risks before, during, and after hazardous events, with social resilience as a key dimension (Gaillard and Mercer, 2013; Shaw, 2012; Tanwattana and Toyoda, 2018).

Schools are a strategic space for disaster risk reduction (DRR) because they reach children and adolescents at formative ages and can help extend a culture of prevention into families and communities (Ronan and Johnston, 2005; Amri et al., 2022). However, research shows that natural hazards are often addressed in school materials in a fragmented and overly theoretical way, frequently emphasising physical descriptions of phenomena while offering limited connection to everyday experiences, local contexts, or practical guidance on how to act before, during, and after an event (Morote Seguido and Souto González, 2020; Morote Seguido and Olcina, 2022). This gap is particularly relevant in multi-hazard countries and regions where floods, wildfires, heatwaves, earthquakes, coastal hazards, and other risks may co-exist, and where preparedness requires applied, context-sensitive competencies (Tiggeloven et al., 2026). In this landscape, higher education, and teacher-education programmes in particular, play a crucial role. Studies with pre-service teachers in different settings point to persistent training needs and incomplete risk representations, which can shape how DRR content is interpreted in the classroom and how it connects with students' everyday lives and local risk contexts (Almeida et al., 2020; Morote Seguido and Hernández, 2020).

At the same time, a growing body of research explores serious games for DRR education, showing that simulated decision environments can help learners test "what-if" alternatives and reflect on the consequences of risk-management choices (Madani et al., 2017; Tan and Nurul-Asna, 2023; Kerlow et al., 2020; Gonzales et al., 2026). Both board and digital formats have been used to familiarise players with preparedness and response actions while fostering discussion about responsibilities, coordination, and collective action, for example through widely disseminated educational games and toolkits (UN/ISDR and UNICEF, 2004; UN/ISDR, 2007) and through simulation-based role-playing approaches that support participatory learning within CBDRM processes (Kerlow et al., 2020; Tanwattana and Toyoda, 2018; Toyoda, 2020; Toyoda and Tanwattana, 2023). Despite these advances, many serious games for disaster risk reduction continue to privilege scenarios centred on the onset of natural hazards, as well as on preparedness and immediate response, while prevention, long-term mitigation, and post-disaster recovery receive comparatively less attention, and their articulation with formal educational goals is not always explicit (Madani et al., 2017; Ducatti et al., 2026; Solińska-Nowak et al., 2018). In addition, hazard representations are frequently generic, with limited attention to the specific combinations of natural risks, institutional frameworks and cultural references that characterise countries or regions, and relatively few games are explicitly designed for teacher education (Giuffrè et al., 2025; Taillandier and Adam, 2018). There is therefore a need for DRR-oriented games that (i) explicitly address the full DRR cycle: prevention, preparedness, response and recovery; (ii) situate hazards and measures in a recognisable local context, and (iii) can be meaningfully integrated into teacher-education programmes to support DRR teaching and learning through participatory experiences.

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Despite growing interest in serious games for disaster risk reduction, relatively few studies have examined analogue game designs explicitly tailored to pre-service teacher education, and even fewer have explored how selected stages of the DRR cycle can be translated into explicit learning tasks through gameplay (Solińska-Nowak et al., 2018; Taillandier and Adam, 2018; de Ruiter et al., 2021; Ducatti et al., 2026; Giuffrè et al., 2025). In response to this gap, this study presents *Heroes of Disaster*, a semi-cooperative board game designed for initial primary teacher education that incorporates selected actions and decision-making situations related to disaster risk reduction through role-based play, inquiry tasks, and evidence-informed protection measures. The game was designed to support three educational objectives: (i) recognising appropriate protective actions associated with different natural hazards and stages of the DRR cycle; (ii) helping students reflect on their ability to recognise hazards, assess preparedness and response measures, and communicate protective actions; and (iii) promoting a positive, cooperative, and classroom-oriented learning experience with a community-aware dimension. The classroom implementation was evaluated through the following research questions:

RQ1. What changes are observed in pre-service primary teachers' protective-action judgements and self-reported preparedness behaviours after participating in Heroes of Disaster?

RQ2. What changes are observed in students' self-perceptions of DRR-related skills, preparedness, and risk awareness after the game-based intervention?

RQ3**.** How do participants appraise *Heroes of Disaster* as a cooperative and classroom-oriented learning resource?

By addressing these questions, the study contributes to the literature on DRR education through a design-grounded approach that integrates the educational foundations of the game, its implementation in an authentic university context, and the analysis of students' responses.

2 Theoretical framework

2.1 Serious games for natural-hazard disaster risk reduction

Serious games are designed with a primary purpose beyond entertainment, most commonly education, training, communication, or behaviour change, while still leveraging the motivational and experiential qualities of play (Michael and Chen, 2005; Susi et al., 2007). In the field of natural-hazard disaster risk reduction (DRR), they have been increasingly used to engage learners with natural hazards and their impacts, protective actions, and institutional responsibilities in ways that are difficult to achieve through expository instruction alone (Tanwattana and Toyoda, 2018; Vázquez-Vílchez et al., 2025; Solińska-Nowak et al., 2018). Their educational value lies in creating structured decision environments where uncertainty, trade-offs, and cascading consequences can be explored safely and meaningfully (Garris et al., 2002; Crookall, 2010).

From an educational perspective, this experiential and participatory logic aligns with community-based disaster risk management (CBDRM) approaches, which frame risk reduction as a shared community process grounded in local knowledge, collective action, and shared responsibility across the full DRR cycle (Gaillard and Mercer, 2013). In this line, CBDRM-oriented game-based approaches have been proposed to rehearse community participation, coordination, and collective

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decision-making in risk contexts (Tanwattana and Toyoda, 2018). Serious games can operationalise these principles by placing learners in social decision settings where they negotiate priorities, coordinate roles, and reflect on how individual actions interact with collective outcomes. In this paper, CBDRM is used as a conceptual lens to frame the participatory and collective dimensions of DRR learning, rather than to claim a full, community-embedded CBDRM intervention. Accordingly, references to CBDRM indicators are intended to clarify which community-based capacities are rehearsed through gameplay and inquiry tasks, and how these capacities would translate to real-world CBDRM practice when enacted in local contexts.

A distinctive feature of serious games in DRR is that learning is embedded in game mechanics: rules, feedback loops, and rewards encode simplified representations of hazard dynamics and risk management strategies. Players are therefore required not only to recall information but also to interpret cues, allocate limited resources, coordinate with others, and reflect on the consequences of choices, activities aligned with complex decision-making in socio-environmental contexts (Garris et al., 2002; Crookall, 2010). Reviews of the empirical literature suggest that serious games can be at least as effective as traditional approaches for knowledge gains and may offer added benefits for motivation, engagement, and higher-order reasoning, although outcomes depend strongly on the coherence between learning goals, narrative framing, mechanics, and facilitation (Connolly et al., 2012; Wouters et al., 2013; Nabong and Opdyke, 2024; Vázquez-Vílchez et al., 2025).

More recently, design-oriented research has highlighted that the effectiveness of serious games in DRR hinges on aligning content with the user experience: intended learning outcomes must be supported by the interaction structure, the feedback provided to players, and the social dynamics promoted by the game (Nabong and Opdyke, 2024; Vázquez-Vílchez et al., 2025). This perspective resonates with more preventive and territory-oriented approaches to risk governance (Giuffrè et al., 2025).

2.2 Serious games on natural hazards: scope, audiences, and disaster phases

Recent literature has classified serious games in disaster contexts according to hazard type, target audience, platform, mechanics, and the phase of the disaster management cycle they address. Reviews of the field highlight a predominance of scenarios focused on floods and earthquakes, alongside frequent use of digital, simulation-based, and role-playing formats that foreground decision-making and coordination among actors (Solińska-Nowak et al., 2018; Ducatti et al., 2026). Taken together, these contributions indicate that the response phase tends to concentrate a substantial share of designs and evaluations, whereas mitigation and recovery/reconstruction are comparatively less represented, and that many games primarily target professional audiences, with fewer initiatives developed specifically for communities or the general public (Ducatti et al., 2026).

Beyond these thematic patterns, the literature also points to recurring constraints in the empirical evidence: evaluations are often context-bound and rely on modest sample sizes and short-term outcome measures, which limits cross-study comparability and the generalisability of findings (Ducatti et al., 2026). Consequently, authors call for greater diversification of both the disaster phases addressed, more explicitly integrating prevention/mitigation, preparedness, response, and recovery, and the intended audiences, alongside more robust evaluation designs capable of assessing impacts beyond immediate changes in knowledge or attitudes (Solińska-Nowak et al., 2018; Ducatti et al., 2026). Accordingly, exploratory and design-oriented

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studies remain important for generating actionable evidence on how specific game features translate into learning and engagement outcomes in real educational settings.

2.3 Board games for disaster risk reduction education

Although digital simulations dominate the serious-games landscape in DRR, board games and other analogue formats have gained visibility as accessible, low-cost tools that support discussion, negotiation, and collaborative problem-solving in face-to-face settings. Their educational value is closely linked to this co-present interaction, as players must justify decisions, negotiate competing priorities, and build shared interpretations of risk and responsibility throughout gameplay, in ways that are closely aligned with the educational aims of DRR (UNDRR, 2015). Recent work on the co-creation of the *Disaster Ready!* board game further highlights the potential of analogue formats to connect DRR education with locally grounded risk experiences and participatory learning processes (Wainman et al., 2026).

An increasing number of board games address natural hazards and disaster risk reduction through role-based play, scenario- and card-driven dynamics, and simplified decision environments. For example, Hazagora (Mossoux et al., 2016) and Riskland (UN/ISDR and UNICEF, 2004) depict multi-hazard contexts and require players to coordinate choices about protective measures and collective response. Other analogue designs focus on specific hazards and behavioural guidance: earthquake-oriented games such as *Treme-Treme* (Ferreira et al., 2016) and *Do It Right: Be Safer!* (Solarino et al., 2021) use cards, dice, and board-based tasks to raise awareness of non-structural vulnerabilities and rehearse protective actions. Hybrid approaches have also been developed in higher education, such as SPRITE, an agent-based simulation used with engineering students to support decision-making for coastal flooding (Taillandier and Adam, 2018).

At the same time, the literature still points to a limited presence of board-game designs that explicitly integrate the different phases of the disaster cycle through participatory and cooperative mechanics (Giuffrè et al., 2025; Ducatti et al., 2026).

In this context, *Heroes of Disaster* and its implementation with pre-service primary teachers contribute to addressing current gaps in the DRR game literature. The present study examines the educational potential of Heroes of Disaster among pre-service teachers, a target group whose role as multipliers of risk education has been comparatively under-represented in empirical evaluations (Ducatti et al., 2026; Giuffrè et al., 2025; UNDRR, 2015; Vázquez-Vílchez et al., 2025). Its cooperation-oriented design is consistent with CBDRM perspectives and with prior work using game-based approaches to support participatory learning and collective action in DRR contexts (Tanwattana and Toyoda, 2018; Gaillard and Mercer, 2013). In this sense, *Heroes of Disaster* contributes as an analogue, multi-hazard serious game that addresses key DRR concepts through semi-cooperative, role-based mechanics and selected actions associated with different phases of the DRR cycle.

3 Game design: *Heroes of Disaster*

Heroes of Disaster is a semi-cooperative educational board game that situates players within a fictional Spanish community exposed to multiple natural hazards over a relatively short time frame. The game introduces the logic of disaster risk reduction

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(DRR) through decision-making situations in which players must select, justify, and negotiate appropriate protective measures in response to different hazards. Although each player has the individual goal of being the first to reach the final square on the board, survival is only possible if the group collectively deploys enough effective actions. The design therefore combines competitive incentives (the race to safety) with strong cooperative dependencies (shared risk and collective decision-making), aiming to model both individual and community resilience in disaster contexts.

3.1 Components

The game used in this study includes the following components: one game board; six role cards and six corresponding tokens; twelve disaster cards; one hundred protection cards; ten wildcard cards; thirty challenge cards; twelve chaos cards; a printed rulebook.

The board represents a stylised map of Spain, including the Iberian Peninsula and the Canary Islands, with fifty numbered spaces forming a path towards a final "safe zone" (Fig. 1). Along this path, hazard icons indicate the locations of the main natural risks considered in the game: flooding, tsunamis, heatwaves, wildfires, earthquakes and volcanic eruptions, placed in regions with documented events (e.g. tsunami risk along the Gulf of Cádiz, seismicity around Granada and Barcelona, volcanic activity in the Canary Islands). This layout functions as a simplified risk map that introduces players to the spatial distribution of major hazards in Spain and provides a starting point for discussing why some regions are more exposed than others.

Figure 1. Game board of *Heroes of Disaster*, based on a stylised map of Spain, including the Iberian Peninsula and the Canary Islands, and showing, through hazard icons, representative natural hazards: a volcanic eruption in the Canary Islands (La Palma, 2021), earthquakes in Granada and Barcelona (high-seismicity areas), and a tsunami along the Cádiz–Huelva coast (linked to the 1755 Lisbon earthquake). The board also includes flooding in the Valencian Community, torrential rainfall in northern Spain, wildfires in Galicia and Extremadura, and a heatwave in Madrid, reflecting the extreme temperature events affecting central Spain.

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Role cards represent key DRR actors (civil-protection staff, firefighters, healthcare workers, volunteers, a forestry ranger and a seismologist) (Fig. 2). Each role provides specific advantages in certain situations, such as bonus protection points for disasters or the ability to help other players more efficiently. These asymmetries highlight the complementarity of professional profiles and the multi-actor nature of risk governance, while at the same time supporting identification with real-world DRR roles.

Figure 2. Role cards and tokens. The cards represent professional profiles that are key to disaster risk reduction (DRR), and each card is paired with a token used to identify the player and mark their position on the game board.

Disaster cards portray six types of events: flood, earthquake, tsunami, volcanic eruption, heatwave and wildfire, selected because of their recurrence and potential impact in the Spanish context (n = 12 cards; Fig. 3). The game also includes 100 protection cards that translate disaster risk reduction into concrete, real-world measures spanning mitigation/prevention (n = 15), preparedness (n = 21), response (n = 49) and recovery (n = 15) (e.g., assembling an emergency kit, identifying safe routes, heat-health advice, sheltering strategies) (Fig. 4 and Figs. S1-S4 in the Supplement). These measures were curated from publicly accessible informational sources (official guidelines, fact sheets, preparedness checklists, and response protocols) produced by national and international agencies such as Civil Protection, the Centers for Disease Control and Prevention (CDC), BeSafeNet, CENAPRED, the Red Cross, the Instituto Geográfico Nacional (IGN), the Ministry for the Ecological Transition and the Demographic Challenge (MITECO), and regional authorities in Andalusia. The specific guidance documents used to inform the design of the protection cards are listed in the Supplement (Table S1). In gameplay, each card provides a protection value that underpins scoring and collective decision-making. Importantly, a subset of these actions explicitly strengthens community resilience by promoting coordination, mutual aid and responsible communication, for instance, assisting others during evacuation, facilitating support and donations, and reducing the impacts of misinformation, thereby reinforcing the shared, collective dimension of risk management.

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Figure 3. Disaster cards representing six types of natural hazards recurrently affecting Spain: floods, earthquakes, tsunamis, volcanic eruptions, heatwaves, and wildfires. All disaster cards were designed by the authors using Freepik assets, in accordance with the corresponding licence.

Figure 4. Examples of protection cards representing selected actions associated with different phases of the disaster risk reduction (DRR) cycle. Visual design elements were created using Canva and Freepik resources, together with official civil-protection iconography, to ensure clarity, recognisability, and alignment with institutional guidance. Relevant third-party assets are credited in accordance with their respective licensing requirements.

Wildcard cards introduce generic advantages that can be thematically interpreted as flexible resources or emergent support mechanisms (for instance, redrawing cards, protecting another player or mitigating the effect of a penalty). Chaos cards, in contrast, represent the consequences of inadequate preparedness or maladaptive decisions, such as infrastructure damage, blocked roads or misinformation (Fig. 5). They impose penalties like loss of points, card removal or forced movement backwards on the board, thereby modelling cascading impacts and poor risk governance.

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Figure 5. Chaos cards. Visual design elements were created using Canva and Freepik resources, together with official civil-protection iconography, to ensure clarity, recognisability, and alignment with institutional guidance.

Challenge cards constitute the core of the game's inquiry-based component (Fig. 6 and Figs. S5-S7 in the Supplement). Each card proposes a cooperative task, for example, analysing a flood-risk map, designing an emergency kit, planning donation boxes after a disaster, simulating a heatstroke response or discussing personal earthquake experiences, and is linked via QR codes to curated digital resources (videos, interactive web pages, news reports, technical factsheets) from scientific and institutional sources (Table S2). Players must search, synthesise and discuss information to produce a written or oral answer, which can later be used for formative assessment in the classroom. In this way, the game integrates both analogue and digital materials and invites players to engage directly with the kinds of DRR resources they might later use as teachers.

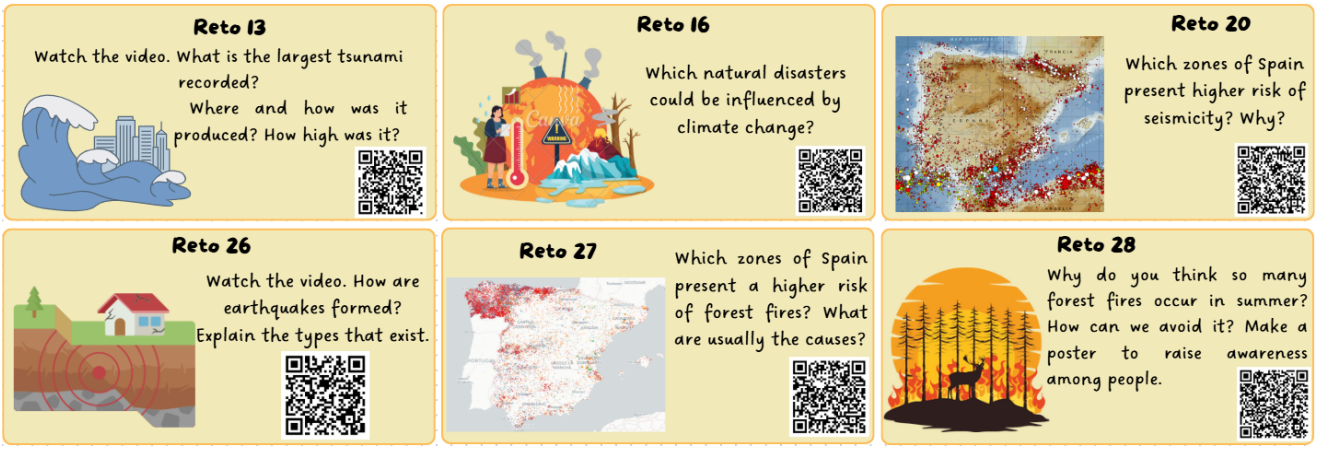

Figure 6. Examples of Challenge cards. Visual design elements were created using Canva and Freepik resources, together with official civil-protection iconography, to ensure clarity, recognisability, and alignment with institutional guidance.

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To reflect selected phases of disaster risk reduction and community-oriented capacities, the challenge cards were systematically classified according to (i) the DRR phase(s) primarily addressed by each task (prevention through recovery, or combinations thereof), (ii) the social resilience attributes fostered (e.g. risk knowledge, social support, leadership, inclusiveness, adaptability), and (iii) CBDRM process and outcome indicators used as training-relevant analogues (e.g. participatory risk assessment, community planning, local learning systems, early-warning practices, or drills and simulations), following Tanwattana and Toyoda (2018). From this perspective, the mapping highlights how the challenge cards articulate capacities and practices that are conceptually aligned with CBDRM, with potential relevance for community-oriented risk reduction settings. Table 1 presents illustrative examples of this classification, while the complete dataset is provided in the Supplement (Table S3).

Table 1. Classification of selected challenge cards according to DRR phase, social resilience attributes, and CBDRM (community-based disaster risk management) process and outcome indicators, based on Tanwattana and Toyoda (2018).

Challenge (example)	DRR phase	Social resilience attribute(s)	CBDRM process/outcome indicator(s)
Challenge 1: Assemble an emergency kit	Preparedness	Leadership; community and individual preparedness; access to economic resources	(4) Community risk management plan; (6) Community-managed implementation
Challenge 2: Design a donation box	Recovery	Social support; inclusiveness; leadership; access to economic resources	(6) Community-managed implementation
Challenge 3: Understand the return period	Prevention	Risk knowledge and awareness of hazard consequences; adaptability; planning	(7) Community learning system
Challenge 4: Understand resilience and its types	Prevention	Adaptability and capacity to accept change; shared community beliefs and values	(3) Building community ties and understanding; (7) Community learning system
Challenge 7: Analyse a flood-risk map	Prevention & Preparedness	Disaster management planning; risk knowledge; knowledge of community assets; functional spaces for response/recovery	(3) Community hazard-vulnerability-capacity mapping; (4) Participatory risk assessment/management
Challenge 8: Measures to reduce flood risk	Prevention	Disaster management planning; diversity of skills/trained personnel; functional spaces for response/recovery	(4) Community risk management plan; (5) Community planning for risk management
Challenge 12: Tsunami protection at the beach and warning others	Response	Social support; collective efficacy; community and individual preparedness	(3) Building community ties and understanding; (7) Community learning system; (8) Community early-warning system
Challenge 14: Heatstroke	Response	Social support; collective efficacy; community and individual preparedness	(4) Participatory risk assessment/management; (6)

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simulation and assisting others			Community-managed implementation; (6) Community drills/simulations; (7) Participatory monitoring and evaluation
Challenge 20: Earthquake risk map	Prevention	Disaster management planning; risk knowledge; knowledge of community assets; functional spaces for response/recovery	(3) Community hazard-vulnerability-capacity mapping; (4) Participatory risk assessment/management
Challenge 28: Awareness poster on wildfires	Prevention	Leadership; shared community beliefs/values; network connectivity	(3) Building community ties and understanding; (7) Community learning system

Note: The numbering in parentheses (e.g., (3), (4), (6), (7), (8)) refers to the CBDRM process and outcome indicators defined by Tanwattana and Toyoda (2018). Because these indicators are numbered in separate lists in the original framework, some numbers recur. The original numbering is retained here to preserve traceability to the source framework.

3.2 Core rules and game flow

At the beginning of a session, each player selects a role card and places the corresponding token on the starting square of the board. All players then draw five protection cards to form their initial hand, representing their current level of preparedness. Each round consists of three main phases:

Hand management and cooperation.

Before revealing the hazard for that round, players may discard any number of protection cards and draw the same number from the deck. They may also negotiate and exchange cards with others. This stage is intended to foreground cooperative planning and the redistribution of resources as a form of community resilience: players must decide whether to keep strong cards for themselves, share them with those in greater need or collectively build a balanced distribution of measures.

Disaster resolution.

A disaster card is revealed, indicating the hazard to which all players are simultaneously exposed. Each player then selects one or more protection cards from their hand that they consider effective for that specific hazard. The cards are placed face up on the table and jointly discussed: the group must decide which measures are appropriate and evidence-based for that situation. To "survive" the event, the total number of valid protection cards played must be equal to or greater than the number of players. If this collective threshold is reached, each player advances a number of spaces on the board equal to the sum of the protection values on their own valid cards. If a player has used an incorrect card, for example, a measure appropriate for another hazard, they must move backwards by the number of spaces corresponding to that card's protection value. This makes individual misunderstandings of DRR guidance visible and open to discussion.

Consequences and escalation.

If the group fails to reach the threshold (i.e. fewer valid protection cards than players), they are considered to have responded inadequately. No one advances and a chaos card is drawn, applying an additional penalty (such as losing cards, skipping a turn or moving tokens backwards) that symbolises cascading impacts and poor risk governance. This mechanism reflects the idea that weak or poorly coordinated responses can exacerbate disaster losses even when some individuals act appropriately.

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As players progress along the path, they encounter special star-marked spaces at positions 10, 20, 30, 40 and 50 on the board. When the leading player reaches one of these spaces for the first time, a challenge card is drawn and read aloud. All players must collaborate to complete the task, using digital resources if needed. Successful completion allows the game to continue and provides rich opportunities for discussion, explanation and consolidation of key concepts (e.g. return period, types of resilience, vulnerability to heatwaves, tsunami warning signs or the psychosocial dimension of recovery). Challenge cards can be used flexibly by the instructor, either during the game or in follow-up sessions, as prompts for deeper inquiry.

The first player to reach square 50 is recognised as having achieved the highest level of individual resilience and effective resource management. However, the game does not end at this point. Instead, play continues until all participants have reached safety. Those who have already finished can still contribute protection cards in subsequent rounds to help lagging players overcome disasters and penalties. This extended end game is designed to simulate post-disaster solidarity and collective recovery processes, reinforcing the notion that resilience is not solely an individual attribute but also a property of communities.

3.3 Educational aims, learning outcomes and targeted competencies

For the purposes of the game's educational design, the aims of *Heroes of Disaster* were operationalised into three main objectives. The first focused on supporting students' recognition of appropriate protective actions associated with different natural hazards and stages of the DRR cycle. The second aimed to help students reflect on their ability to recognise hazards, assess preparedness and response measures, and communicate protective actions. The third sought to promote a positive, cooperative, classroom-oriented learning experience that also emphasises civic responsibility, participation, and community-oriented DRR. These objectives are developed below by describing how gameplay and challenge-card activities target knowledge, skills, attitudes, and classroom-oriented competencies relevant to DRR and to students' future role as teachers.

The first educational objective is addressed by requiring students to connect disciplinary knowledge of natural hazards with appropriate protective actions. The game is designed to help students consolidate disciplinary knowledge of six key natural hazards (floods, earthquakes, tsunamis, volcanic eruptions, heatwaves, and wildfires) and the processes and conditions that shape them, including earthquake generation, tsunami formation, flood dynamics, wildfire behaviour, and the atmospheric conditions associated with heatwaves. Rather than presenting this content in a purely expository way, the game invites students to mobilise and apply these ideas when deciding which protection measures are adequate in specific scenarios.

The second objective is supported through inquiry-oriented and reflective tasks. Players must formulate hypotheses about the potential consequences of different actions, search for and critically evaluate information from authoritative sources (e.g. civil-protection agencies, public-health institutions, scientific organisations), and interpret risk maps, infographics and other graphical representations linked through the challenge cards. These tasks mirror practices they are likely to promote in their own classrooms and therefore serve as a form of situated teacher learning. In addition, *Heroes of Disaster* requires students to justify their choices, explain why certain measures are or are not appropriate for a given hazard and stage of the DRR cycle, and produce written or oral answers to the challenges. These tasks reinforce their ability to articulate arguments, use technical vocabulary appropriately, and adapt explanations to different audiences.

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The third objective is reflected in the cooperative and community-oriented structure of the game. The game is designed to create opportunities for students to negotiate strategies with their peers, reach collective decisions under time and information constraints, and consider the protection of other players and of fictitious household members or neighbours. This community-oriented dimension is further developed through the affective and social aspects of resilience embedded in the game design. The situations and dilemmas included in the cards are intended to encourage reflection on risk perception, attachment to home and possessions, empathy towards vulnerable groups, such as children, older adults, or people with disabilities, and the importance of a sense of community during and after disasters. Experiencing the tension between individual advancement on the board and collective safety provides an entry point for discussing ethical and emotional dimensions of decision-making in risk contexts.

From a DRR perspective, the game incorporates individual and community resilience by prompting players to consider their own preparedness and knowledge, identify gaps, adjust their strategies, and participate in shared decision-making about collective safety. Several challenges, summarised in Table 1, are explicitly mapped to social-resilience attributes and CBDRM process and outcome indicators, such as leadership, social support, inclusiveness, shared learning, and participatory risk assessment. In this sense, the game not only communicates "what to do" in the face of hazards but also foregrounds how protective decisions can be negotiated collectively and understood within community-oriented risk-reduction processes.

Overall, the game mechanics bring together the three educational objectives by supporting the selection and justification of appropriate protective actions, fostering inquiry, reflection, and communication tasks that make the timing and contextual appropriateness of DRR decisions experientially salient. The game mechanics also promote a cooperative, participatory, community-oriented, and classroom-relevant learning experience. For pre-service primary teachers, engaging with DRR in this way can contribute to their professional identity as educators capable of integrating disaster risk reduction topics into their future practice, designing similar game-based activities for their pupils, and acting as mediators of DRR knowledge within their schools and local communities.

4. Implementation

To explore the educational potential of Heroes of Disaster in teacher education, we conducted a classroom implementation at the University of Granada (Spain). This section outlines the intervention design, classroom procedure, and exploratory evaluation strategy used in this study.

The intervention was implemented during a regular 90-minute class session in the third year of the Primary Education degree and combined a pre-test/post-test questionnaire design with a lightly facilitated gameplay session. Although 52 students completed the delayed post-test, the matched analytical sample comprised 49 pre-service primary teachers who completed both the pre-test and the delayed post-test and whose responses could be matched across the two measurement points. The matching procedure and the number of unmatched responses are reported in the Supplement (Table S4). Pre-test/post-test analyses were therefore restricted to the 49 matched cases, whereas post-test-only appraisal outcomes were analysed using all

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students who completed the delayed post-test (n = 52). Among these participants, 76.4 % identified as women, and ages ranged from 19 to 28 years, with most students being 20 years old (40.0 %) or 21 years old (30.9 %).

Data were collected using two structured questionnaires administered before the activity and two weeks afterwards (Tables S5 and S6). The overall design of the instruments was partly informed by the questionnaire developed by Tsai et al. (2020) to assess serious game-based learning for disaster prevention. More specifically, selected items related to perceived skills and self-awareness, enjoyment and interest in learning, and attitudes towards DRR and community participation were translated and adapted to the context of pre-service primary teachers and to the *Heroes of Disaster* framework. By contrast, the DRR-related judgement block was developed specifically for this study to capture how participants interpreted and responded to typical multi-hazard risk situations addressed through the game. These items were not treated as a standardised measure of objective DRR knowledge, but as indicators of protective-action judgements, self-reported preparedness behaviours, and recognition of safer responses in context-sensitive risk situations.

At the beginning of the session, students were informed about the aims of the activity and the voluntary nature of participation. They first completed the pre-test individually via an online form, without consulting external sources. The pre-test comprised two sections: (i) perceived DRR-related skills and self-awareness, based on adapted items from Tsai et al. (2020), and (ii) a study-specific set of Likert-type statements designed to probe baseline DRR-related judgements and intuitive responses in typical DRR situations.

After the pre-test, the authors introduced *Heroes of Disaster*, explained its main components and rules, and organised students into small groups. Groups then played with light facilitation: the authors clarified rules-related questions and encouraged discussion when controversial decisions or misconceptions emerged, while avoiding direct instruction on DRR content during gameplay.

The post-test was administered online two weeks later via a link distributed through the university's virtual learning platform. It replicated the pre-test DRR-related judgement and self-awareness items and added post-intervention evaluation items addressing perceived learning, clarity, motivation, realism, classroom usefulness, cooperation, and enjoyment, most of them adapted from Tsai et al. (2020). Open-ended questions invited students to comment on what they liked most about the game, what they would change, and whether the experience influenced their ideas for teaching natural hazards (Table S6). The two-week interval was chosen to move beyond immediate recall and capture early consolidation and short-term retention of DRR-related judgements and perceptions.

The questionnaire blocks and composite outcomes were aligned with the research questions, while remaining consistent with the educational objectives described in Sect. 3.3. The pre-test/post-test DRR-related judgement items, particularly the protective-action judgements and preparedness behaviours composite, were used to address RQ1. The pre-test/post-test items assessing students' self-perceptions of their DRR-related skills, preparedness, and risk awareness were used to address RQ2. The post-intervention appraisal items were used to explore RQ3, while the civic responsibility and participation items provided complementary information on the community-aware dimension of the learning experience. Thus, the evaluation linked the research questions to both pre-test/post-test changes and post-test-only appraisals.

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All Likert-type items were coded on a 1–5 scale. Negatively worded items were reverse-coded so that higher scores consistently indicated safer, more preventive, or more favourable responses. For the items administered at both the pre-test and the delayed post-test, three composite outcomes were constructed: general DRR-related self-perceptions and risk awareness, protective-action judgements and preparedness behaviours, and total repeated DRR-related items. For the post-test-only items, two additional composite outcomes were calculated: civic responsibility and participation, and educational game appraisal. Internal consistency was estimated using Cronbach's alpha.

Descriptive statistics were calculated for all composite outcomes. Pre-test/post-test differences were analysed using paired-samples t-tests with the matched sample, reporting mean differences, 95 % confidence intervals, p-values, and Cohen's dz as a within-subject effect-size estimate. Wilcoxon signed-rank tests were also conducted as a non-parametric sensitivity check. Post-test-only outcomes were compared with the neutral midpoint of the Likert scale using one-sample t-tests. Item-level analyses were treated as exploratory; therefore, false discovery rate correction was applied to the corresponding p-values. All statistical analyses were conducted in R (version 4.5.3).

5. Results and discussion

Results are presented according to the three research questions. RQ1 examines changes in participants' protective-action judgements and self-reported preparedness behaviours; RQ2 addresses changes in their self-perceptions of DRR-related skills, preparedness, and risk awareness; and RQ3 examines their appraisal of *Heroes of Disaster* as a cooperative and classroom-oriented learning resource.

Pre-test/post-test analyses were conducted with the 49 participants who completed both questionnaires and whose responses could be matched across the two measurement points. Table 2 summarises the changes observed across the repeated DRR-related outcomes. Post-test-only appraisal outcomes were analysed using the 52 participants who completed the delayed post-test.

Table 2. Pre-test/post-test changes in DRR-related outcomes in the matched sample.

Outcome	Items	α pre	α post	Pre M ± SD	Post M ± SD	Δ [95% CI]	p	dz	Wilcoxon	Interpretation
Protective-action judgements and preparedness behaviours	15	0.67	0.69	3.67 ± 0.53	4.02 ± 0.49	0.35 [0.23, 0.46]	< .001	dz = 0.86 (large)	< .001	Significant increase
General DRR-related self-perceptions and risk awareness	7	0.83	0.85	3.85 ± 0.67	4.00 ± 0.62	0.15 [-0.08, 0.38]	0.195	dz = 0.19 (negligible)	0.174	Descriptive increase
Overall repeated DRR-related index	22	0.71	0.83	3.73 ± 0.44	4.01 ± 0.49	0.28 [0.16, 0.41]	< .001	dz = 0.67 (moderate)	< .001	Significant increase

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Note: p values are based on paired-samples t-tests conducted with the matched sample (n = 49). α pre and α post refer to Cronbach's alpha before and after the intervention. dz refers to Cohen's within-subject effect size. Wilcoxon values correspond to non-parametric sensitivity checks. Higher scores indicate more favourable DRR-related responses.

5.1 Changes in protective-action judgements and self-reported preparedness behaviours

The first research question examined whether participation in Heroes of Disaster was associated with changes in pre-service teachers' protective-action judgements and self-reported preparedness behaviours. As summarised in Table 2, the clearest improvement was observed in the composite outcome comprising protective-action judgements and preparedness behaviours. Mean scores for protective-action judgements and preparedness behaviours increased from 3.67 ± 0.53 in the pre-test to 4.02 ± 0.49 in the delayed post-test, with a mean difference of 0.35 points, 95 % CI [0.23, 0.46]. This change was statistically significant, $t(48) = 5.99$, $p < .001$, and showed a large within-subject effect size, $dz = 0.86$. The total repeated DRR-related index also increased significantly, from 3.73 ± 0.44 to 4.01 ± 0.49, $\Delta = 0.28$, 95 % CI [0.16, 0.41], $t(48) = 4.68$, $p < .001$, $dz = 0.67$. Taken together, these findings indicate that participation in *Heroes of Disaster* was associated with improved protective-action judgements and self-reported preparedness behaviours. This composite-level pattern is consistent with research suggesting that serious games can support applied learning and decision-making in complex scenarios when game mechanics are meaningfully aligned with educational goals (Connolly et al., 2012; Wouters et al., 2013; Nabong and Opdyke, 2024; Vázquez-Vílchez et al., 2025).

Exploratory item-level analyses of the repeated pre-test/post-test items were used to inspect the individual responses underlying the composite-level changes in protective-action judgements and self-reported preparedness behaviours and are reported in Supplementary Table S7. They generally showed positive descriptive changes in several items, particularly in protective-action and preparedness-related responses, although most individual changes did not remain statistically significant after FDR correction.

5.2 Changes in DRR-related self-perceptions and risk awareness

The general DRR-related self-perceptions and risk awareness block showed only a small, non-significant increase, from 3.85 ± 0.67 in the pre-test to 4.00 ± 0.62 in the delayed post-test, $t(48) = 1.32$, $p = .195$, $dz = 0.19$ (Table 2). Thus, the findings do not indicate a significant change in students' broader self-perceptions of their DRR-related skills, preparedness, and risk awareness.

Because the general DRR-related self-perceptions and risk awareness items capture self-perceptions rather than demonstrated performance, the small, non-significant increase observed in this block should be interpreted as a descriptive pattern of perceived preparedness and reflective awareness rather than as evidence of objective DRR competence. The divergence between these findings and the significant changes in protective-action judgements suggests that contextualised decision-making and broader self-perceived DRR competence may represent distinct educational outcomes.

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5.3 Appraisal of the game as a cooperative and classroom-oriented learning resource

Students' evaluation of the game as a cooperative and classroom-oriented learning resource was highly positive overall (Fig. 7). Agreement or strong agreement was particularly high for learning DRR concepts (92.3 %), understanding real-life cases of natural disasters (86.5 %), applicability of the simulated scenarios to real-life situations (84.6 %), teamwork being more enjoyable than playing alone (90.4 %), and the motivational role of the scoring system (82.7 %).

A substantial proportion of students also agreed or strongly agreed that the game allowed them to simulate DRR decision-making processes (78.8 %) and motivated their interest in DRR topics in daily life (69.2 %). Responses to the cognitive-load item were also favourable, with 63.5 % agreeing or strongly agreeing that the amount of knowledge included in the game did not overwhelm their learning, although 26.9 % selected the neutral option (Fig. 7).

The post-test-only composite outcomes for civic responsibility and participation, and educational game appraisal, also showed statistically significant scores above the neutral midpoint of the scale, supporting the overall positive interpretation of students' post-intervention evaluation (Supplementary Table S8). Together, these results indicate that participants positively appraised *Heroes of Disaster* in terms of perceived learning, real-life applicability, motivation, cooperation, and usability. This is particularly relevant when serious games are designed to combine educational content, interaction, and user experience (Nabong and Opdyke, 2024; Vázquez-Vílchez et al., 2025).

Alongside this generally positive appraisal, the cooperative and social dimension of the game emerged as a central component of the experience. Interaction with peers, discussion of strategies, and shared reflection on priorities and protective actions are consistent with the educational rationale of the game and, more specifically, with a CBDRM perspective that emphasises participation, shared responsibility, and the collective construction of capacities at all stages of disaster risk management (Gaillard and Mercer, 2013; Shaw, 2012; Tanwattana and Toyoda, 2018).

In this sense, the value of Heroes of Disaster lies not only in its potential to support DRR-related learning, but also in offering future teachers a concrete example of how DRR can be approached through participatory, cooperative, and inquiry-oriented classroom dynamics. This is particularly relevant in initial teacher education, where previous studies have shown that natural-hazard education often remains fragmented, overly theoretical, or weakly connected to everyday life and practical decision-making (Morote Seguido and Souto González, 2020; Morote Seguido and Hernández, 2020; Morote Seguido and Olcina, 2022), while teachers' disaster preparedness is also shaped by beliefs related to self-efficacy, perceived benefits, barriers, and cues to action (Dasci Sonmez and Gokmenoglu, 2023).

From this perspective, the game is broadly consistent with a community-oriented approach to risk reduction, emphasising participation, cooperation, shared responsibility, and contextualised protective decision-making (Tanwattana and Toyoda, 2018; Gaillard and Mercer, 2013).

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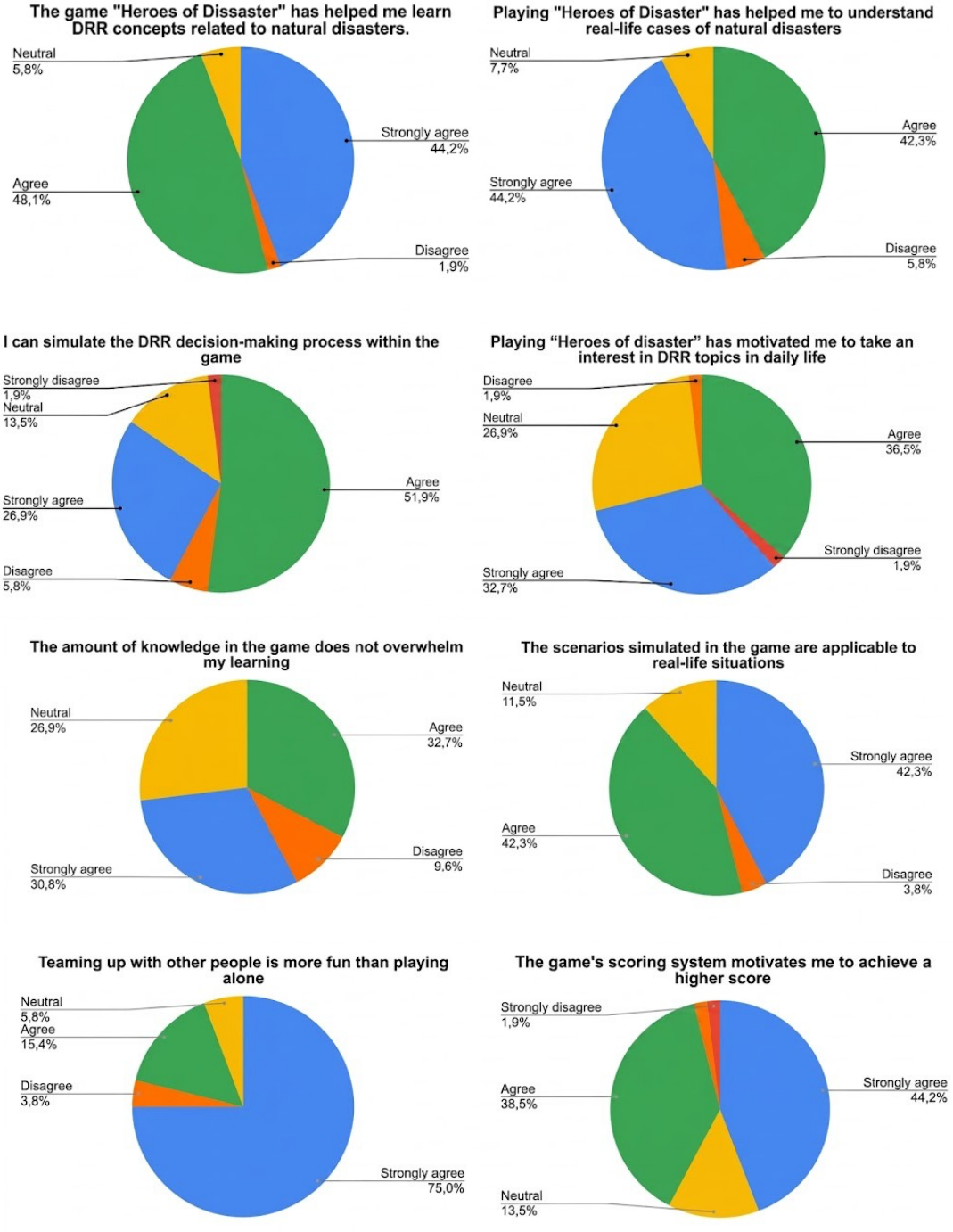

Figure 7. Students' evaluation of *Heroes of Disaster* after the intervention, based on the 52 participants who completed the delayed post-test.

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6. Conclusions

The main contribution of this study is twofold. First, it introduces *Heroes of Disaster* as a semi-cooperative board game designed to support DRR education in pre-service primary teacher education by connecting hazard-related knowledge, evidence-informed protective actions, cooperative decision-making, and inquiry-based challenge activities. Second, it reports on a classroom implementation that provides exploratory evidence on changes in protective-action judgements and self-reported preparedness behaviours, changes in DRR-related self-perceptions and risk awareness, and participants' appraisal of the game as a cooperative and classroom-oriented learning resource. Taken together, the findings suggest that *Heroes of Disaster* may support more preventive and evidence-aligned protective-action judgements and provide a positively appraised learning experience that is cooperative, usable, classroom-oriented, and community-aware, while changes in students' broader self-perceptions of their DRR-related skills, preparedness, and risk awareness were smaller and non-significant. These results provide a grounded starting point for further research and development of analogue, semi-cooperative DRR games in teacher education. Beyond these findings, the study also suggests that analogue, semi-cooperative DRR games may offer a useful way of bringing selected principles associated with a community-based disaster risk management (CBDRM) perspective into teacher education, particularly those related to participation, shared responsibility, mutual support, and community-oriented protective reasoning. From this perspective, the value of *Heroes of Disaster* lies not only in helping future teachers identify appropriate protective actions, but also in engaging them in collaborative and reflective processes that are relevant to the educational mediation of disaster risk.

These findings should be interpreted in light of the exploratory nature of the study. The intervention was conducted in a single university context and did not include a comparison group. However, the delayed post-test, administered two weeks after gameplay, provides a useful indication of students' DRR-related judgements and perceptions beyond the immediate learning experience. Future research should examine the game in more diverse educational contexts and explore how the learning processes fostered by the game may inform classroom practice and community-oriented DRR education.

Ethics statement

This study was conducted as part of a regular educational activity with pre-service primary teachers at the University of Granada. Participation in the research component was voluntary, and students were informed about the aims of the activity and the anonymous treatment of their responses. No sensitive personal data were collected, and the data were analysed in anonymised form. The study involved no intervention beyond normal classroom-based educational practice and posed no foreseeable risk to participants.

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Code and data availability

No software code was developed as part of this study. The anonymised data supporting the analyses presented in this paper, together with the material needed to reproduce the reported results, will be made available in a FAIR-aligned public repository upon acceptance of the manuscript.

Author contributions

TMS and MVV were involved in the overall research process, including the conceptualisation and design of the study, the development of the educational intervention, the implementation of the classroom activity, data collection, data analysis, interpretation of the results, and manuscript preparation and revision. MVV was responsible for funding acquisition.

Competing interests

The authors declare that they have no conflict of interest.

Financial support

This work was supported by grant PID2024-160481OB-I00, funded by MICIU/AEI/10.13039/501100011033 and by the European Regional Development Fund (ERDF), European Union.

Acknowledgements

The authors would like to thank the participating students for their involvement in the classroom implementation and for sharing their views during the activity. AI-assisted tools were used during manuscript preparation to support language checking, style refinement, and editorial consistency. The authors reviewed and approved the final text and take full responsibility for the content of the manuscript.

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