

LB/TH/22/2025

TH5856

**DEVELOPMENT OF A GAMIFIED APPLICATION TO
ENHANCE COMMUNITY EDUCATION ON RISK-
SENSITIVE URBAN DEVELOPMENT**

Mohamed Rifat Mahamood

238017D

Master of Science (Major Component of Research)

Department of Town and Country Planning

Faculty of Architecture

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DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date: 20/03/2025

The above candidate has carried out research for the PhD/MPhil/Master's thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

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ACKNOWLEDGEMENT

This study was completed with the support of a number of people, each of whom contributed in different ways. I am thankful to each and every person for their assistance, ideas, and support, and most importantly, for their commitment to ensuring that this research is a success. I am especially appreciative of their dedication.

First and foremost, I would like to express my gratitude towards my research supervisors, Dr. Chathura De Silva and Dr. Nayomi Kankanamge for their guidance and unwavering support in ensuring the success of my research study. Their extensive knowledge and thorough direction have been of great. I am glad for the opportunity to conduct research as a student under their guidance.

I would also like to extend my sincere appreciation to my fellow colleagues, Ms. Daneesha Ranasinghe and Ms. Nuwani Kangana, for their continuous support, encouragement, and contributions, which played a crucial role in the successful completion of this research.

I would like to thank TRANSCEND research project titled "Technology Enhanced Stakeholder Collaboration for Supporting Risk-Sensitive Sustainable Urban Development". The "Disaster Defenders" game is a part of this project and hosted by the University of Salford, UK, and funded by the Global Challenges Research Fund (GCRF) in the United Kingdom

I am also deeply thankful to the Principal and staff of C.W.W. Kannangara College, Mathugama, for their generous support in facilitating the testing process with Grade 6 students. Their cooperation and willingness to contribute to this research are greatly appreciated.

Finally, I would like to extend my deepest appreciation to my supportive parents, relatives, and friends, who have always provided me with the courage and strength to face all the challenging situations

ABSTRACT

Flooding is the most significant natural hazard that Sri Lankans experience annually. The education and awareness associated with it remain traditional, with teachers feeding students with their expertise. The traditional educational mode needs to change to a more exciting and engaging mode. Globally, disaster education has already upgraded to an interactive and innovative level. Use of gamification or serious gaming to provide disaster education to the children can be considered as an example for such innovative learning and teaching model. This model is successfully applied in disaster education in countries such as Australia, The United States of America, New Zealand, Japan, Philippines, Italy and many more. However, such gamified applications are either limited to board games or do not have comprehensive learning experience. Therefore, this study focuses on developing a desktop gamified application to improve flood disaster education for school children. The methodology was designed under four phases: (a) Initiation; (b) Production; (c) Testing and (d) Releasing. After the said four phases the developed game was tested using 175 children and youngsters as the sample. Two testing iterations have been completed on the game prototype and final game is developed for launch. More than 85% of the participants responded favorably to the gamified application, which also indicated that they had raised awareness of floods. This research contributes to the growing field of serious gaming and gamification in disaster education by integrating cognitive, behavioral, and experiential learning theories into an interactive digital platform. The study also provides an empirical framework for assessing the effectiveness of gamified applications in knowledge retention and user engagement. The project delivers an interactive, scalable, and replicable educational tool that can be adapted for broader disaster preparedness initiatives. The insights from this study can inform policymakers, educators, and game developers in designing effective, engaging, and context-specific disaster education programs for vulnerable communities.

Keywords: Gamification, Serious Gaming, Disaster Awareness, Flood Hazard, Child Education

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LIST OF ABBREVIATIONS

Abbreviation	Description
SG	Serious Game
AR	Augmented Reality
VR	Virtual Reality
XR	Mixed Reality
PC	Personal Computer
AI	Artificial Intelligence
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
UNDRR	United Nations Office for Disaster Risk Reduction
UNISDR	Former United Nations Office for Disaster Risk Reduction
ADDIE	Analysis, Design, Development, Implementation, and Evaluation
PUN	Photon Unity Networking
NPC	Non-Player Character
GIS	Geographic Information System
QSH	Quake Safe House

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LIST OF PUBLICATIONS

Title	Journal	Progress
Development of Gamified Application to Enhance Flood Disaster Education	Urban Education	Under Review
Levelling Up Disaster Education: How Gamified Apps Empower Children and Youth—A Systematic Review	International Journal of Disaster Risk Reduction	Under Review
Use of gamification and serious games for disaster education; practices, trends and way forward	The 15 th International Conference on Sustainable Built Environment 2024	Presented the Full Paper Submitted

CHAPTER 1

INTRODUCTION

1.1 Background of the study

1.1.1 Flood Disaster and Sri Lanka

Natural and manmade disasters pose a substantial threat to the general well-being and safety of people globally. Every 100-year floods have a direct impact on 23% of the global population, which amounts to 1.81 billion individuals. Out of that population, 1.24 billion individuals reside in South and East Asia, with Sri Lankans accounting for 16% - 23% of this population (Rentschler et al., 2022). According to the Madhubhashini (2019), a total of 2.9 million individuals were impacted by flooding in Sri Lanka between the years 1974 and 2004. Between 1990 and 2018, the total cost of damages and losses caused by floods in Sri Lanka was around USD 2 billion (Hewawasam & Matsui, 2023). However, due to recent climatic changes, the present situation may be even more unfavorable currently.

To minimize the potential hazards to people and infrastructure, it is crucial to effectively handle and prevent disasters using proactive strategies. Hence, the significance of disaster awareness as a proactive strategy for disaster management cannot be exaggerated. The ability to identify, comprehend, and react to various emergencies is an essential talent need in a resilient society (Galluccio, 2021). Governmental agencies and educational institutions recognize the need of disaster preparedness and are placing more emphasis on developing new approaches for comprehensive disaster education programs (Coates, 2020; Kešetović, 2021).

1.1.2 Traditional disaster education methodology

Disaster Education is the training of individuals for various disasters, like floods, by thinking about emergency responses and strategizing appropriate actions. Leaflets, public service announcements, signage, warning sirens, broadcast television and radio, social media, classroom instruction, familial and community education, and text messaging are few methods of communication (Preston, 2012). This technique has

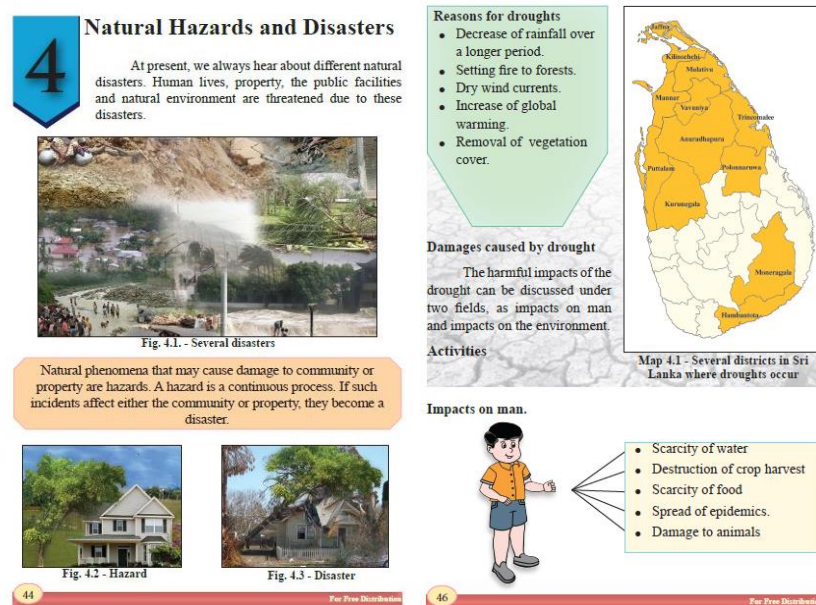
demonstrated efficacy in disaster prevention and mitigation, enhancing disaster awareness and information acquisition (Meiqin et al., 2018).

Disaster education is critically important, especially in areas susceptible to flooding (Yüksel & Akbel, 2023; Hidayat & Yatminiwati, 2023). Floods can cause significant harm to individuals and property; thus, it is crucial to spread knowledge and derive lessons from past adverse events. The human mind is predominantly influenced by childhood education; so, disaster education should commence with foundational education for the younger generation (Tsai et al., 2015).

In Sri Lanka, children receive education about disasters at the age of 12 (grade 7) within the school curriculum. Consequently, the curriculum lacks disaster education for children up to the age of 12. The grade 7 curriculum included teaching on disasters such as droughts, floods, landslides, cyclones, lightning, tsunamis, and earthquakes (Educational Publications Department, 2023). At the age of 12, teachers impart conceptual knowledge regarding disasters, including their types, causes, consequent damages, and repercussions (Figure 1.1).

Figure 1.1

Grade 7 geography text book



Note. Source from Educational Publications Department (2023)

In addition to the school curriculum, children have the chance to engage in awareness programs regarding disaster preparedness, conducted by non-governmental organizations (NGOs) and volunteer communities (Figure 1.2). However, these

programs are exceedingly rare, and only a limited number of children get the opportunity to enroll.

Figure 1.2

Disaster Risk Reduction Training to children in Hambantota 2022



Note. Source from Rupasinghe (2022)

The bulk of disaster education programs today utilize a systematic framework comprising components for cognitive, skill-based, and emotive learning (Tsai et al., 2020). Teachers impart conceptual knowledge to students, explaining the mechanisms of disasters and their harmful impacts. Following the dissemination of knowledge, teachers want students to utilize that information to develop skills and respond correctly during emergencies. Nevertheless, it has resulted in decreased student interest in disaster education and prompted inquiries over the effectiveness of teachers or specialists in conveying their experiences to students.

1.1.3 Gamification

To improve disaster education, 'gamification'—the incorporation of game-like elements in non-game, real-world contexts such as disasters—was implemented among schoolchildren and at-risk communities (Kankanamge et al., 2022; Xiang G et al., 2021; Rosyada et al., 2023; Le Dé et al., 2021). Gamification integrates intrinsic motives, including satisfaction, acquiring new knowledge, enjoyment of the game, curiosity, value, and pressure or tension. Additionally, extrinsic motives include the accumulation of rewards, enhancement of scores, and participation in leaderboards (Kankanamge et al., 2022). Consequently, gamified applications aim to provide instruction to players by using both intrinsic and extrinsic motivations.

Studies have shown that experiential education motivates students to learn about disaster avoidance better than lectures (Tsai et al., 2020). Gamification and constructivist learning theory allow students to actively construct knowledge through

action rather than passively accepting information (Gampell et al., 2020; 2021; Sunarharum et al., 2021). Thus, disaster management education and awareness require real experience and training.

Initially, the focus was on board and dice games, such as Magnitude (UNISDR, 2011), Dissolving Disasters, and Paying for Predictions (Red Cross Red Crescent Climate Centre, 2023), aimed at improving disaster education among the general public. Recently, the advancement of technology has facilitated the expansion of online game-based learning into the realm of disaster education. Examples of available web-based games include Stop Disasters! (UNDRR, 2018), Cikeas – Cileungsi Overflow (Christoffel, 2023), and Battle of Flooding Protection (Tsai et al., 2020). Gamified applications enhance repetitive interactions with the game, resulting in improved retention and recall of the conveyed knowledge (Matsuno et al., 2020).

1.1.4 Why Children and Youth?

Children and youth represent the future leaders of the nation; teaching these demographic yields more significant benefits than educating adults. The norms and lifestyle of the majority of adults in Sri Lanka are immutable by any means (Roberts, 1994). Consequently, it is worthwhile to endeavor to educate the new generation. In Sri Lanka, disaster preparedness and response primarily stem from prior experiences. Individuals respond based on their experiences, rendering children and youth susceptible to disasters due to their lack of prior exposure to such events. Consequently, it is highly vital to educate children and youth, as the climate is undergoing significant changes currently.

The advantages of educating children and youth encompass their ability to impact adults via love and compassion, positioning them as effective change agents in society (McGee et al., 1977; Schwartz, 2010). Furthermore, early disaster education can foster the development of enduring preparedness and safety practices. The concept of gamification is exceedingly popular among the younger generation, whose preferences typically encompass enjoyment and adventure, exploration and discovery, skill enhancement with spatial awareness, and social connection.

A gamified approach to disaster education can effectively teach children how disasters occur, their causes, and the steps needed to mitigate their impacts. In the case of flood disasters, children learn how land use, urbanization, deforestation, and climate change

contribute to flooding and how their own choices can reduce risks and enhance preparedness. The game-based learning approach educates them on flood warning signs, evacuation procedures, safe shelter locations, and emergency responses, equipping them with life-saving knowledge and decision-making skills. By building and managing a simulated town in a flood-prone area, children experiment with different mitigation strategies such as constructing flood barriers and reinforcing community resilience. This interactive learning experience not only enhances their disaster awareness but also empowers them to actively participate in preparedness efforts within their homes, schools, and communities.

1.2 Objectives of the Study

This study aims to develop a gamified application for school children to enhance the flood disaster education and covers following three objectives in this study,

1. To review and analyses gamified applications related to flood and other disasters
2. To develop a gamified application to educate children
3. To enhance user involvement in flood disaster education through participatory game designing

1.3 Research Question

To achieve the aforementioned objectives, the research consists of two research questions.

1. What are **the key design elements and characteristics** that enhance the efficacy of a gamified application in educating **children and youth** about flood disaster?
2. To what extent does the use of a gamified application contribute to the **awareness raising** pertaining to flood disasters among children and youth ?

1.4 Limitations

The primary constraint is the restricted technological expertise in game production, rendering the game development aspect of the research particularly tough. In Sri

Lanka, there exists a small number of games developed in the domains of disaster management and education. Consequently, only a limited number of resource individuals were available for consultation during the course of the study.

Obtaining actual ground data to recreate the game in 3D became difficult due to the scarcity of open-source data. Consequently, the game was designed in 2D utilizing an isometric perspective to construct a fictional neighborhood for player interaction.

The most difficult aspect of this research is to launch and mobilize the gamified application among the public. Although the game raises awareness about a significant issue, the games played by children and youth are predominantly for fun rather than educational goals.

1.5 Scope of the Research

This study centers on the development of a desktop gamified application aimed at improving flood disaster education for children and adolescents. The research examines the integration of serious gaming ideas with disaster awareness to provide an interesting and dynamic educational experience. The study covers the comprehensive design, development, and testing of the application, according to a systematic process including literature review, prototype development, iterative testing, and final release. The intended audience for this research comprises youngsters aged 6 to 12, since this demographic is particularly amenable to gamified learning and has the capacity to impact disaster preparation practices within their families and communities. The game integrates flood simulations and decision-making situations to educate youngsters about the causes, effects, and mitigation techniques related to floods. User feedback is obtained via internal expert assessments and external evaluations with children, using pre-test and post-test assessments to evaluate knowledge retention and engagement.

The study is limited to the development of a desktop application and does not include mobile or web-based versions. The research focuses on flood disaster education, excluding other disasters like earthquakes, tsunamis, or landslides. The research examines the immediate effects of gamification on disaster education but does not investigate long-term behavioral modifications or information retention over prolonged durations. The game encompasses geographical principles pertaining to

flood danger but lacks the integration of real-time GIS data or dynamic hazard mapping. The emphasis is on streamlined instructional frameworks that successfully engage young learners. Notwithstanding these constraints, the study offers significant insights into the function of gamification in disaster education and establishes a basis for future developments in interactive learning instruments for disaster preparation.

1.6 Organization of the Thesis

This thesis has four main chapters, each focusing on a distinct facet of the research process. Chapter 1 presents the research by outlining the background and context of flood disaster education, highlighting the need for gamification in fostering disaster awareness among children and adolescents. It delineates the research objectives, research questions, scope, and limitations of the study.

Chapter 2 delineates the methods and materials used in the study. It delineates the systematic literature and application review procedure, including the criteria for choosing relevant gamified applications. Furthermore, it delineates the four-phase game development process, including initiation, production, testing, and release. This chapter examines the data gathering methodologies and assessment procedures used to assess the efficacy of the developed application.

Chapter 3 delineates the findings and discussion of the analysis. The examination starts with a review of current gamified apps for disaster education, emphasizing significant technology and design elements. The chapter thereafter concentrates on the development and evaluation of the gamified application, including insights into user engagement, educational results, and feedback acquired from testing sessions. The discourse examines the efficacy of gamification in improving disaster awareness and compares the results with previous studies.

Chapter 4 concludes the thesis by summarizing the main results, contributions, and implications of the research. It evaluates the efficacy of the developed gamified application in flood disaster educating and examines its possible applications outside the limits of this study. The chapter explores limits and offers ideas for future study, including potential enhancements and the extension of gamified disaster education to wider audiences and diverse platforms.

CHAPTER 2

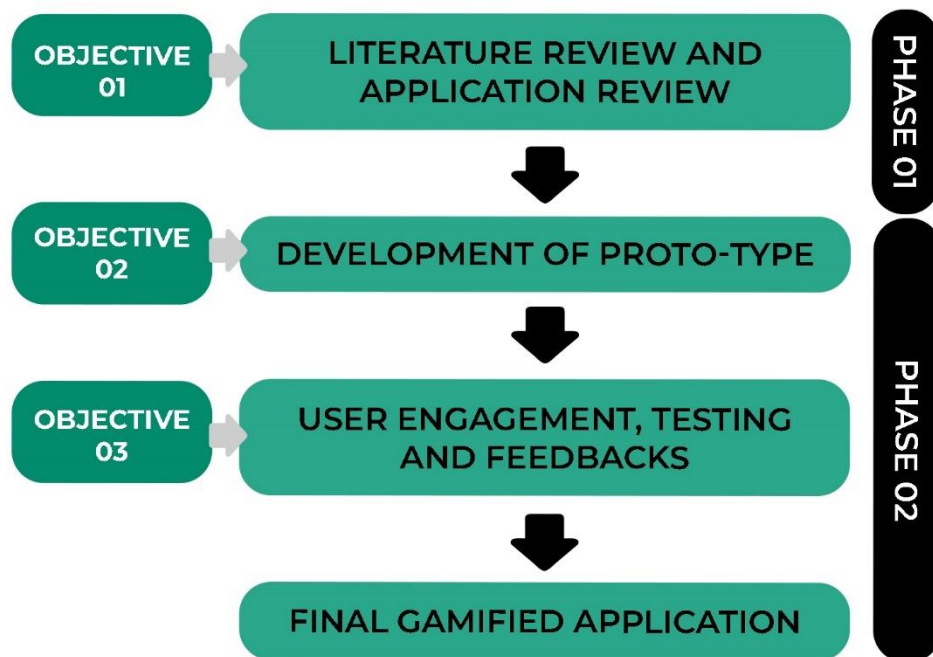
METHODOLOGY AND MATERIALS

2.1 Overall Methodology

The research employed an inductive technique for the execution of the study and the development of a gamified application. The study is launched to solve a deficiency in the disaster education curriculum in Sri Lanka. Consequently, the study employed an empirical methodology, incorporating recurrent testing alongside knowledge derived from systematic reviews.

Figure 2.1

Overall Methodology



The methodology corresponds with the three objectives of this research. The initial phase involves doing a review of literature and applications. The games examined in the study are played and studied to identify positive elements to add into the new gamified application and unfavorable aspects to exclude. This also facilitated the identification of the research gap in this study.

The next phase involves the development of a gamified application informed by the findings from the review. The application is built through multiple testing rounds,

incorporating regular feedback from the desired target groups. The development of the gamified application will be the core of this research, providing a systematic framework for a new approach to academics in the field of gamification.

2.2 Phase 01 – Literature Review and Application Review

2.2.1 Screening process and criteria

This study conducted a comprehensive literature review to analyze gamification research within disaster education. The research concentrated on objectives, particular disasters examined, data gathering techniques, research methodology, software used, game development processes implemented, gameplay of the gamified applications, and the resultant conclusions. The systematic literature review was performed in accordance with the principles established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; [Liberati et al., 2009](#)).

The process consists of four phases: (1) Identification, (2) Screening, (3) Eligibility, and (4) Inclusion (Figure 2.2). The identification phase involved the formulation of keywords and their variations. The study employed the phrases gamification, disaster education and awareness, flood mitigation, disaster risk reduction, disaster management, and video games to discover appropriate studies for review. The databases Google Scholar, ResearchGate, and Web of Science were examined during the screening procedure.

The identification technique involves searching the database using the supplied keywords and their variations in the titles and abstracts of the studies. Only articles composed in English have been taken into account for this. Nevertheless, a restricted quantity of studies, specifically fewer than 50, was identified utilizing code 1.

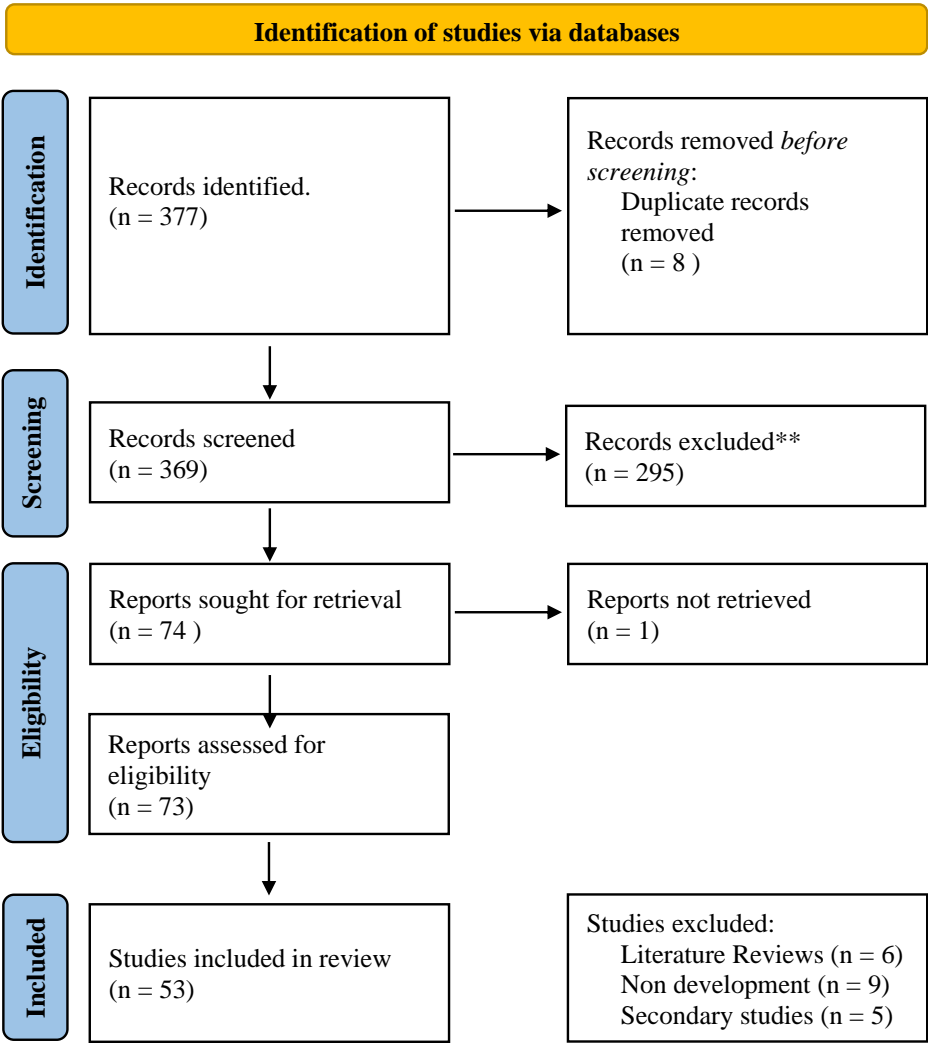
Search Code 1 ;

TITLE-ABS-KEY ((gamification OR gamified application OR video game OR serious game) AND (disaster OR flood OR earthquake OR tsunami OR fire OR landslide OR hurricane OR volcano) AND (education OR mitigation OR awareness OR training OR learning OR teaching OR preparedness OR response)) AND (LIMIT-TO (Language, "English"))

Search Code 2 ;
*ANY ((gamification OR gamified application OR video game OR serious game)
 AND (disaster OR flood OR earthquake OR tsunami OR fire OR landslide OR
 hurricane OR volcano) AND (education OR mitigation OR awareness OR
 training OR learning OR teaching OR preparedness OR response)) AND
 (LIMIT-TO (Language, "English"))*

To expand the search, articles that include the term in any part of the article can be accessed using search code 2. A total of 377 studies were recognized. Irrelevant and redundant research was removed from the dataset. The criteria for inclusion and exclusion were set at the eligibility phase. The studies were assessed according to these criteria to determine their suitability.

Figure 2.2
PRISMA flow diagram



The inclusion criteria, established based on the research objectives, were as follows: The criteria for selecting articles are as follows: (a) articles published between 2008 and 2023, (b) articles published in conferences, journals, or books, (c) articles that focus on the development of gamified applications for teaching and/or learning, (d) articles that provide evidence or present a theoretical framework for the development of gamified applications, and (e) articles that experiment with gamified applications involving the public, children, or youth. However, the exclusion criteria were as follows: (a) research that focused specifically on boardgames or dice games, (b) studies that focused on non-natural disasters, and (c) studies that did not address the combination of education and gamification. The screening process, in which these criteria were utilized, mostly involved inspecting titles and abstracts.

The number of studies considered at this stage reduced to 369. Following a comprehensive evaluation of the complete text using identical criteria for eligibility, it was determined that 53 research will be incorporated. Ultimately, the chosen studies underwent content analysis, and the findings were presented according to two dimensions: (1) The technologies employed in the development of gamified applications for disaster education, and (2) Strategies employed for testing and deploying the application

2.2.2 Dimension for analysis

The review centers on the two components of the gamified applications developed for disaster education. These applications use several platforms, including personal computers (PCs), mobile devices, web browsers, tablets, augmented reality (AR), and virtual reality (VR), to educate people about disasters. Each of these platforms, however, exerts unique influences on the user regarding immersivity, experience, and learning outcomes. Therefore, it is essential to examine the methodology utilized in the creation of this application to understand and replicate the process for future application development. Thus, the first dimension employed for the research is the technological facet of developing gamified apps, including the platform, software, methodology, and other pertinent elements. No research in the current literature has explicitly investigated the technologies utilized in gamified applications. Consequently, this will rectify the existing study gap and provide insightful perspectives for future initiatives.

Notwithstanding the advancement of these gamified applications, only a limited number have succeeded in engaging the general public and users. For instance, “Stop Disasters!” (Kankanamge et al., 2022; Pereira et al., 2022; Sabo, 2012; Gampell et al., 2020; Sunarharum et al., 2021), “Earth Girl 2” (Gampell et al., 2020), “Treme-treme” (Musacchio et al., 2015), etc. Other gamified applications that have been developed are predominantly confined to scholarly publications. It is essential to assess the factors contributing to the failure of these games to engage the audience and to identify the shortcomings in the mobilization and launch processes. Consequently, as the second dimension, it is essential to comprehend the strategies utilized by these articles to evaluate and implement the generated application. No researcher in the current literature has examined the mobilization strategies for gamified applications within the realm of disaster education. This study will delineate the methods necessary for the effective launch of the gamified application.

2.2.1 Data Collection

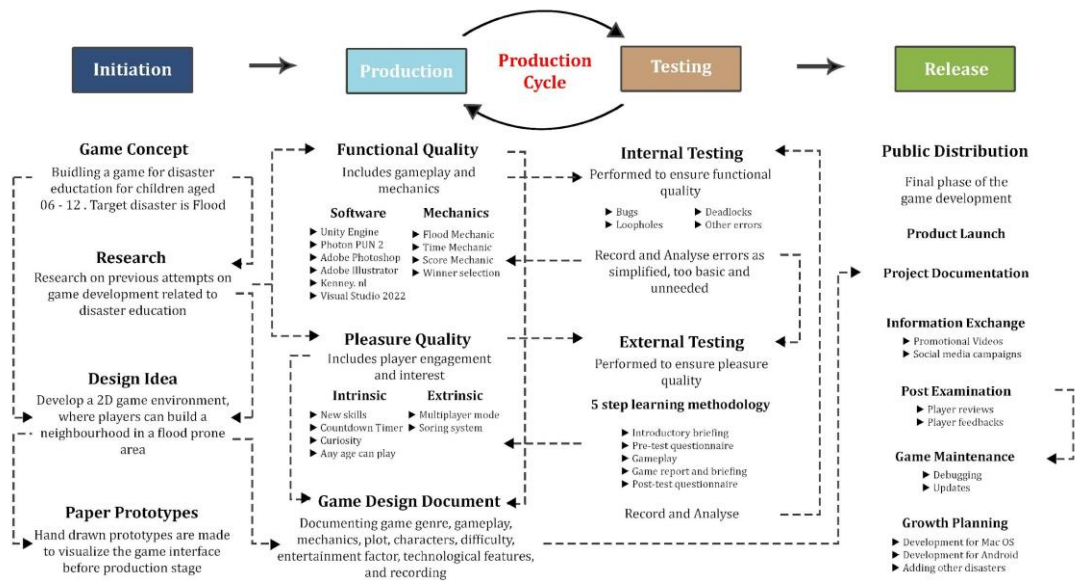
The gamified applications necessary for the review were obtained from secondary sources, including publications by developers, third-party papers, and user reviews of gamified applications. The gamified applications referenced in the study, which inspired the creation of the new application, were included in the review. Furthermore, the gamified applications referenced in the research publications were assessed by empirical investigations involving active engagement with the application, which was subject upon its public accessibility. To obtain more precise information regarding these programs, it is necessary to contact the application developer or the article's author as the primary data source.

2.3 Phase 02 – Development of Gamified Application

According to Figure 2.3, the prototype development process consists of four separate phases: initiation, production, testing, and release. This study utilized a 4-phase methodology adapted from the integration of ADDIE (Wahyudi & Hidayatullah, 2022; Zaini et al., 2020), Experiential Learning Cycle (ELC) (Tsai et al., 2020), Game Development Life Cycle (Sucipto et al., 2023), and Waterfall process development paradigms (Rosyada et al., 2023).

Figure 2.3

Prototype development process



2.3.1 Initiation

At the initiation stage, target group, game features and game user interface were thoroughly studied.

- Target Group

The game has predominantly been aimed at children and youth. The primary reason for this was children's capacity to affect adults via their love and compassion, making them significant agents of change in society. The present cohort of children and youth, known as the alpha generation (born post-2010), exhibits significant proficiency with information and communication technology (ICT) tools and gaming platforms, facilitating the promotion and awareness-raising within a broader community (Augusto Dos Reis, 2018; Schawbel, 2014). Multiple target groups (Figure 2.4) were initially selected for the study, along with their gaming interests and characteristics.

Children aged 10 to 14 comprehend global disaster threats according to their cognitive abilities. They choose superhero-themed games that facilitate study, problem-solving (Gilsenan, 2021; Internet Matters, 2022), and skill enhancement. Social interaction is essential for peer engagement and play (Hou et al., 2022; Rathakrishnan et al., 2023). Individuals aged 15 to 19 prefer competitive multiplayer and role-playing games, reflecting an enhanced awareness of societal challenges and crisis management

(Gilsenan, 2021; Bilgihan et al., 2013; Rathakrishnan et al., 2023). Children in the 06-12 age group have heightened interest and a strong desire to learn about their surroundings (Rathakrishnan et al., 2023). Early disaster education can foster the development of enduring preparedness and safety behaviours. Upon evaluating the objectives and proposed game design, we selected youngsters aged 6 to 12 as the target demographic and developed the game according to their tastes.

Figure 2.4

Analyzed Target Groups

Age Group : 10 – 14 Years	Age Group : 15 – 19 Years	Age Group : 06 – 12 Years
<ul style="list-style-type: none"> • Have cognitive abilities : Understand complex concepts • Growing Awareness around the world : Potential Risk and Challenges posed by disasters • Can help to educate them about DISASTER MANAGEMENT in a FUN and INTERACTIVE WAY 	<ul style="list-style-type: none"> • Mature Have developed cognitive abilities : Can engage in more complex concepts • Growing awareness about social issues and desire to make positive impact : Can understand nuances of disaster management 	<ul style="list-style-type: none"> • Developmental Receptiveness: Children in this age range are at a stage where they are curious and eager to learn about the world around them • Lifelong Habits: Introducing disaster awareness at a young age can help instill lifelong habits of preparedness and safety
<p>Preferences and Gaming Characteristics</p> <ul style="list-style-type: none"> ✓ Exploration & Adventure (Immersive and Imaginary worlds) ✓ Strategy & Problem Solving ✓ Skill Development (Spatial Awareness / Logical Reasoning) ✓ Social Interaction (Compete against peers) ✓ Engaging themes & characters (Superheroes / Fantasy creatures) 	<p>Preferences and Gaming Characteristics</p> <ul style="list-style-type: none"> ✓ Competitive Multiplayer Games (Online Shooters / Battle Royale Games) ✓ Role Playing Games (RPGs) (Immerse in rich storytelling) ✓ Open World & Sandbox Games ✓ Social and Cooperative Games ✓ Mobile Games (Quick and accessible) 	<p>Preferences and Gaming Characteristics</p> <ul style="list-style-type: none"> ✓ Fun and Adventure ✓ Exploration and Discovery ✓ Skill Development ✓ Social Interaction (Compete against peers) ✓ Engaging themes & characters (Superheroes / Fantasy creatures) ✓ Colorful and Engaging Visuals
<p>(Gilsenan, 2021; Internet Matters, 2022; Hou et al., 2022; Rathakrishnan et al., 2023)</p>	<p>(Gilsenan, 2021; Bilgihan et al., 2013; Rathakrishnan et al., 2023)</p>	<p>(Internet Matters, 2022; Hou et al., 2022; Millar & Baloglu, 2008; Rathakrishnan et al., 2023)</p>

When conducting research involving children, particularly those who may have previously experienced flooding, it is essential to ensure that the study does not cause distress, reinforce trauma, or induce fear. To minimize potential emotional impacts, no visualizations or content were included that could trigger traumatic memories or heighten anxiety. Instead, the game was designed using cartoonish, colorful, and child-friendly visuals to create a safe, engaging, and non-threatening learning environment. The focus is on problem-solving, preparedness, and resilience-building rather than depicting destruction or distressing disaster scenarios. Additionally, all research activities were conducted with parental/guardian consent, and children’s well-being was prioritized throughout the study. By ensuring that the learning experience remains interactive, positive, and empowering, the research fosters awareness and preparedness in a manner that is psychologically safe and developmentally appropriate for young learners

- Game Features

The game has established a fictional neighborhood by the river where the player can construct their own village according to their preferences. The region is susceptible to

frequent flooding, and the town should be constructed with minimal risk to the inhabitants in consideration. The player receives seven building options, encompassing roads and trees. The player must evaluate the decision to utilize building alternatives. Two distinct motivations propel games and gamified applications. Specifically, (i) intrinsic motivations and (ii) extrinsic motivations (Kankanamge et al., 2022). These two factors substantially influence the success and audience engagement of the gamified application.

- Game User Interface

Following the development of the game concept and design, paper prototypes were created (Figure 2.5). The initial procedure generated the game concept and its description. The user interface is designed for children and is compatible with Windows PCs. The color scheme of the gamified application utilized blue and green components to replicate the surrounding environment (Figure 2.6). The soothing colors promote prolonged screen viewing without causing eye strain. Cartoonish visuals and avatars were created to captivate children (Figure 2.7).

Figure 2.5

Paper prototypes



Figure 2.6

Used Color scheme

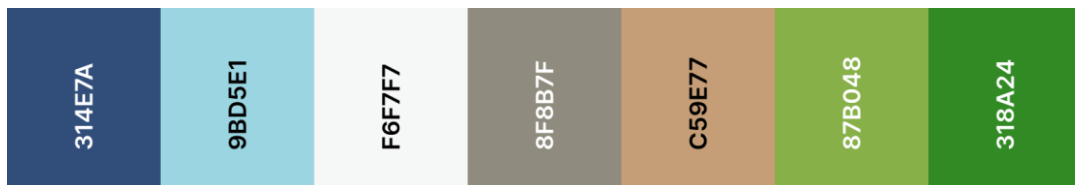


Figure 2.7

Used Anime Characters



The gameplay was engineered to facilitate ease of play. The mouse is utilized to engage in this point-and-click game. The 2D interface was created to simplify player management. The Disaster Defenders focus on children ages 6 to 12; hence, a 3D interface was deemed unnecessary, according to existing research. The prototype employed as large fonts and text sizes, as youngsters like reading them on the game screen. Minimal text was employed in the game, with visual elements predominating. All these elements were crafted to create a user-friendly experience for children.

2.3.2 Production

The design and development of games primarily focused on two key elements. These were: (a) Functional quality and (b) Pleasure quality. The functional quality refers to gameplay and related mechanisms, including logic, mathematics, and game rules. Playtesting and revisions assess functional quality. The level of pleasure has been focused on the enthusiasm players exhibit for the game and the degree of interest they demonstrate. These features must be assessed by questionnaires and the analysis of players' facial and bodily expressions following the completion of the production task (Sucipto et al., 2023).

Figure 2.8

Isometric Building #1 assets package



Note. Source from Kenney (2024)

The isometric tiles of the game were inspired by titles such as "SimCity," "Stop Disasters!" and others. They provide a 3D perspective, even if the game is constructed in 2D. The 2D tile sprites originated from the website kenney.nl. The Isometric Buildings #1 (Figure 2.8) asset package has been downloaded and utilized. Adobe Illustrator and Photoshop were utilized to generate supplementary tile sprites (Figure 2.9) and to design the user interfaces and images, which adhere to a 16:9 aspect ratio. The gameplay in Disaster Defenders was developed on 2D isometric tile maps in Unity Engine version 2022.3.2f1 (Figure 2.10).

Figure 2.9

Used 2D Sprites

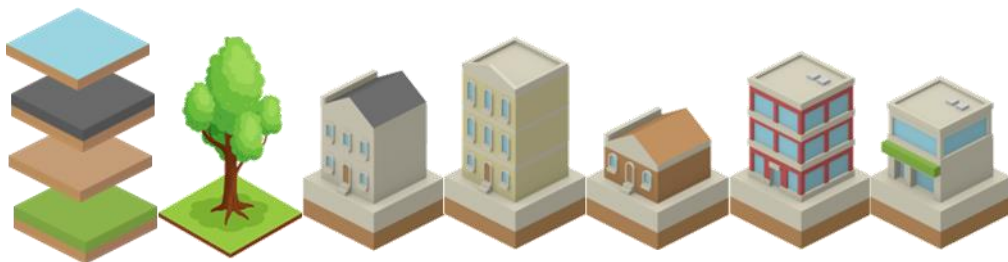
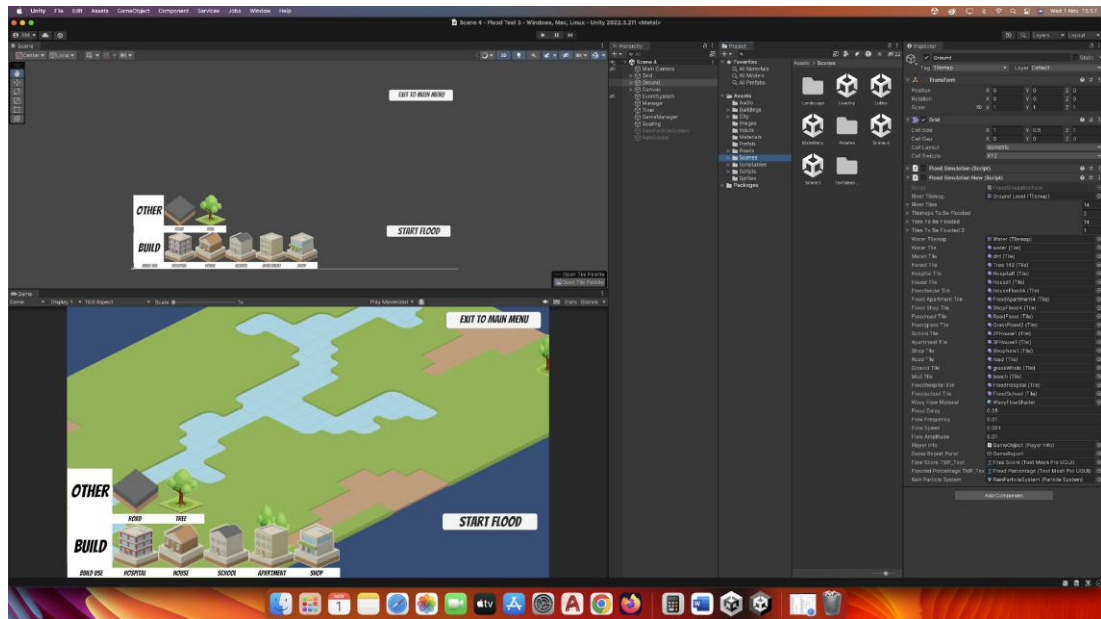


Figure 2.10

Unity Engine

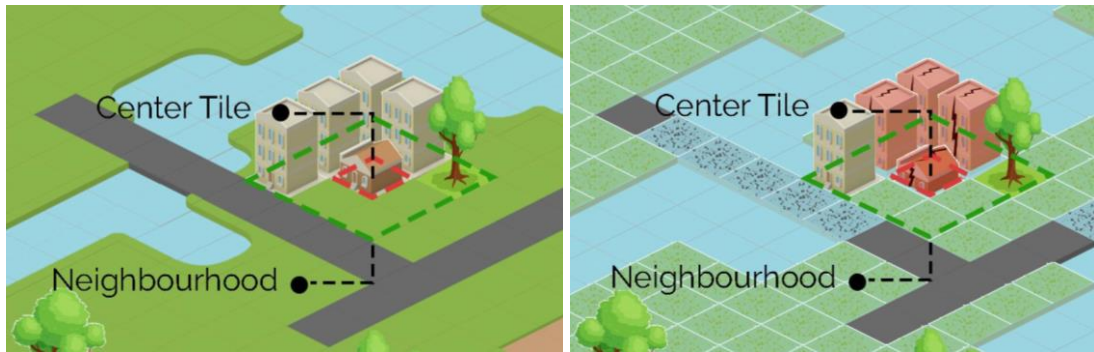


The Photon Engine, available at no cost for non-commercial purposes, served as the Multiplayer Engine. The Photon Unity Networking (PUN) 2 package was utilized to match players into rooms for item synchronization across the network. The programs were coded in C# using Visual Studio 2022.

The game's rules are presently pretty fundamental. Despite being a multiplayer game, it may also be played solo. The player is allotted 5 minutes to construct a neighborhood by incorporating roads and buildings. Following the designated timeframe, flooding will occur, inflicting damage on structures and other assets in susceptible locations. Preliminary flooding transpires as a result of the terrain's gradient and altitude, as per flood mechanics. The concept of cellular automata has since been expanded to include flood mechanisms. The ideas derived from the cellular automata concept for flood mechanics are explained in Figure 2.11

Figure 2.11

Neighbourhood before and after flooding



Note. Figure on left depicts before flooding scenario and figure on right depicts after flooding scenario. Every individual tile within the gaming interface is encompassed by a 3x3 neighborhood, as illustrated in Figure 2.11. The rules were formulated for the central tile, considering three distinct possibilities.

1. The Impact of the Center Tile on Itself
2. The Effects of the Surrounding Eight Tiles on the Center Tile
3. The impact of the center tile on the surrounding eight tiles inside the neighbourhood.

For a given tile, the scenarios were divided into two different events: either a flood event occurred or it did not. This is how the percentage of flood damage was calculated:

$$\text{Flood damage percentage} = \frac{\text{number of flooded tiles}}{\text{number of neighbourhood tiles}} \times 100$$

The percentage of flood damage was determined solely based on the tiles added by the player. As a result, tiles included in the initial scene will be excluded from the calculation. The winner was established based on the highest score and little flood damage. In solo mode, winner is designated as the sole winner.

2.3.3 Testing

The testing was executed in two stages: (a) Internal testing; and (b) External testing. Internal testing was conducted to guarantee functional excellence and to detect and rectify bugs loopholes, deadlocks, and other issues. An internal testing session was conducted with IT instructors from C.W.W. Kannangara Central College, Mathugama

(Figure 2.12), to gather input on proposed adjustments intended to improve children's comprehension of flooding prior to a demonstration session. Additionally, regular internal evaluations were conducted with academic specialists.

Figure 2.12

Demonstration with IT instructors



Errors were recorded and analyzed. Modifications were implemented based on simplified, too basic, or unneeded. To ensure the quality of the experience, attendees of EXMO 2023, the flagship technological exhibition of the University of Moratuwa, and sixth-grade students from C.W.W. Kannangara Central College, Mathugama, engaged in external testing. The prototype is created repeatedly, including feedback from users to enhance responsiveness.

EXMO 2023 was selected because it provided an opportunity to demonstrate the game to a large audience within a short period, allowing for diverse user feedback. Additionally, a significant number of attendees belonged to the target age group, making it an ideal testing environment. Meanwhile, C.W.W. Kannangara Central College, Mathugama, was chosen as it met the key requirements for hosting a structured demo session within a school setting. The school had the necessary facilities to support the testing process, and the student included children with prior flood-related experiences, ensuring meaningful engagement with the game's disaster preparedness objectives. The principal of C.W.W. Kannangara welcomed the initiative and willingly invited the research team to conduct the demonstration, further facilitating a smooth and supportive testing process. The prototype was refined iteratively based on feedback from both testing environments to enhance usability and learning effectiveness.

2.3.4 Release

The game development reached at its final stage and was prepared for public distribution during the release period. The release procedure encompassed product launch, project documentation, information exchange, post-examination, and game maintenance and expansion planning.

CHAPTER 3

RESULTS AND DISCUSSION

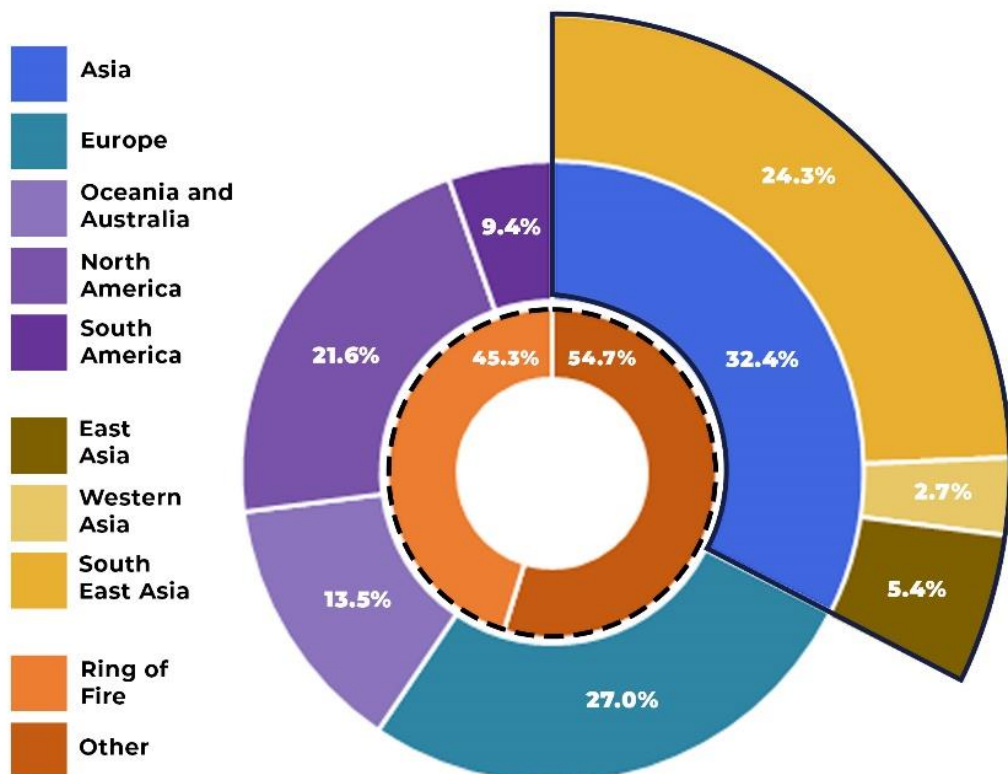
3.1 Phase 01 – Literature Review and Application Review

3.1.1 Existing Gamified Applications

Among the 53 publications reviewed, 42 unique gamified applications were analyzed. These applications were generally assessed according to a standardized set of criteria present in all gamified applications. The factors included: (1) the country where the study was done, (2) the platform on which the gamified application was developed, (3) the scale of the gameplay, (4) the specific disaster addressed, (5) the particular phase of the disaster management cycle, and (6) the target age group.

Figure 3.1

Regions that the reviewed gamified applications belong



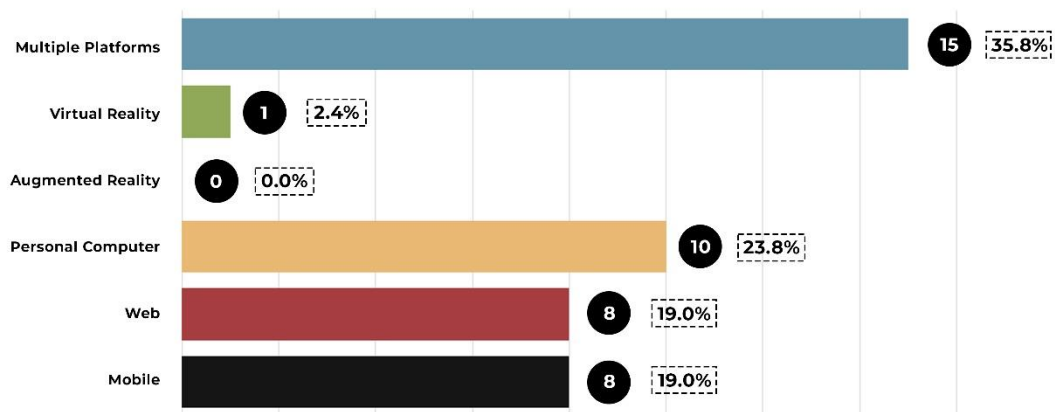
The majority of the research were conducted in Asia and Europe, comprising 12 (32.4%) and 10 (27.0%) studies respectively. The majority of research in Asia is

undertaken in Southeast Asia. No studies originating from Africa were found. Notwithstanding its status as the most populous region in Asia, South Asian nations have not achieved considerable prominence in the use of gamified applications pertaining to disasters. The United States of America has conducted the most studies, totaling 5, followed by Indonesia and Italy, each with 4 studies among the selected articles. Of the 42 applications that integrated gaming aspects, 19 (45.3%) were developed or utilized within the ring of fire.

These gamified applications have been developed for multiple platforms (Figure 3.2), including personal computers (PCs), mobile devices, tablets, virtual reality (VR), and augmented reality (AR). The majority of the assessed gamified applications were developed for many platforms rather than just for one. At now, there are no gamified applications specifically designed for augmented reality. Augmented Reality has been utilized across various platforms, including mobile devices.

Figure 3.2

Platform that gamified application developed



Among the gamified applications examined in the article, 24 (57.1%) were designed for individual scale, indicating that the gaming focused on one single user, with actions impacting only that person. Eight (19.0%) applications were developed for town/city scale, whilst four (9.5%) were built for household scale. Certain gameplays concentrated on river basin or watershed scale, national or continental scale, while one gameplay was executed at the neighborhood scale (Figure 3.3). The restricted number of gameplays at the neighborhood and urban size indicates insufficient focus on analyzing land use and the built environment in the development of gamified applications for disaster education, a crucial element in comprehending disasters.

Figure 3.3

Scale of the gamified application

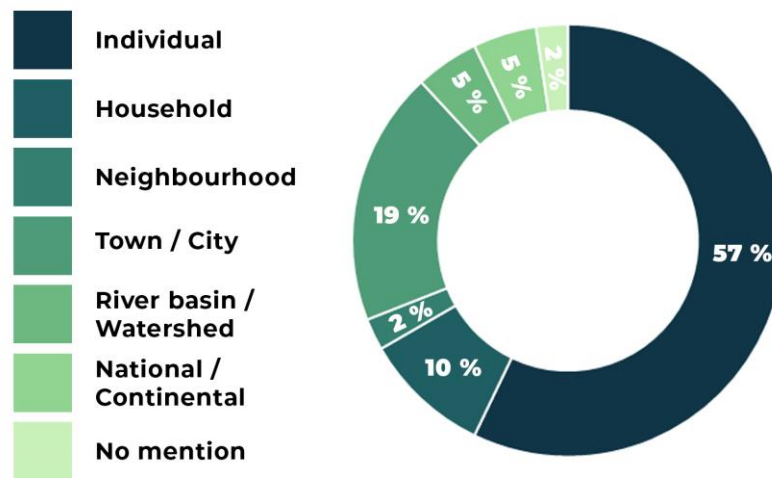
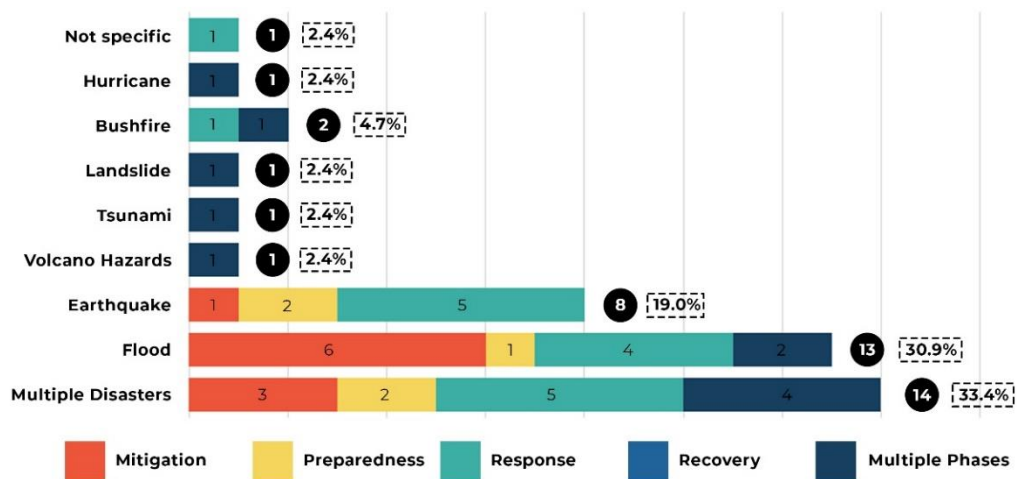


Figure 3.4

Disaster and phase of the disaster management cycle that application focused



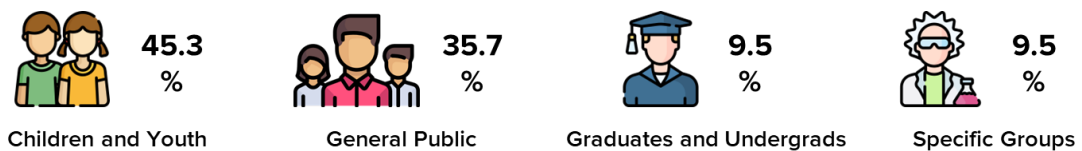
Among the gamified applications examined, 14 (33.4%) discussed multiple disasters concurrently, including floods, earthquakes, and landslides. In the development of gamified applications, the most notable disasters that garner significant interest are floods and earthquakes (Figure 3.4). Upon analyzing the phase of the disaster management cycle targeted by these gamified applications, 16 (38.0%) were explicitly associated with the response phase. This corroborates the conclusions of [Seaberg et al. \(2017\)](#), who determined that the reaction phase of disaster management has been extensively examined, and future research should concentrate on investigating the other stages of disaster management, such as mitigation, preparedness, and recovery.

Furthermore, other gamified applications concentrate on multiple phases of the disaster. The research indicated that none of the gamified applications concentrated solely on the recovery phase of the disaster management cycle.

The reviewed gamified application predominantly focuses on children and youth, including 19 (45.3%) of the 42 applications. Furthermore, 15 applications, constituting 35.7%, are intended for the general public (Figure 3.5). A minority of the applications, 4 (9.5%), is aimed at undergraduate and graduate students, whilst the other 4 applications are directed towards specialized groups, including emergency responders, decision-makers, scientists, local government officials, and humanitarian logistics agents.

Figure 3.5

Target groups of the developed gamified applications



3.1.2 Board games Vs Computer Aided applications in Disaster education

Two categories of gamified applications were incorporated into disaster education. These encompass board games and digital or computer applications. Board and classroom games such as "Magnitude," "Dissolving Disasters," "Paying for Predictions," and "Decisions of the Decade" are highly regarded for fostering disaster awareness (Kankanamge et al., 2020b). These games are intended for many players and are more enjoyable when performed with a larger group of participants (preferably 10-40 players). Seek a game master to supervise and coordinate the gameplay by delivering directions to participants concerning rules and timing. Each game lasts approximately 45 to 60 minutes and requires additional equipment, including cards, beans, cones, chairs, and tables (Red Cross Red Crescent Climate Centre, 2024). These games predominantly emphasize the financial component in player decision-making, while disregarding the spatial dimension. This corroborates the findings of Taillandier & Adam (2018) about the application of serious games in natural risk management. They stated that chance significantly influences the game due to the usage of dice to decide player turns.

Computer-aided applications have predominantly been developed for single-user engagement. Nonetheless, there are occasions when multi-player applications are also developed (Sermet et al., 2020; Teague et al., 2020). The typical duration is between 10 to 15 minutes. The "Stop Disasters!" game presents three unique time levels, each corresponding to a different level of difficulty. Moreover, there exist rapid games like "Quake Safe House," which lasts merely 2 minutes and 20 seconds (Gampell et al., 2021). The program exclusively requires a device, including personal PCs, mobile devices, tablets, and occasionally VR headsets, to enhance immersion. A limited number of gamified applications necessitate internet connectivity; however, the majority of these applications also offer offline versions. Computer-aided programs provide players' complete immersion in a virtual environment within a 2D or 3D spatial framework, offering an engaging and instructive experience for learners. With the automation of these procedures, the presence of a game master to deliver commands or monitor scores and time becomes unnecessary.

Table 3.1

Board games Vs Computer-aided applications

Board games	Computer-aided applications
Mostly multiplayer	Mostly single player
Average 45 - 60 min gameplay	Average 10 - 15 min gameplay
Supplementary equipments required	Device platform required
Prioritize financial factor	Financial factor, spatial factor, human factor considered
Randomness plays a significant role	Player decisions plays a significant role
Limited audio-visual elements	Accessible audio-visual elements

Some board games have been converted into computer applications and available in both formats. Olivares-Rodríguez et al. (2022) transformed the board game "Costa Resiliente" into a video game to educate young demographics on the concept of community resilience. The board game "Extreme Event Game" features an online version designed to teach individuals about community resilience in the face of disasters (National Academy of Sciences, 2024; Medina-Salgado et al., 2024). Olivares-Rodríguez et al. (2022) conducted a study evaluating board games and video games across five dimensions. The five aspects are: (1) Achievement and Challenge, (2) Immersion, (3) Experience, (4) Playability, and (5) Support. Video

games excelled on all five dimensions, primarily because to their automated gameplay, engaging audio-visual components, and reduced cognitive load on players.

3.1.3 Technologies used in developing gamified applications in disaster education

- Platforms

Analysis of gamified applications revealed that 15 (35.8%) are built for multi-platform use (Figure 3.2). They employed various platform combinations to enhance their efforts, with each platform exerting a unique influence on performance. Personal computers, mobile devices, and tablets have served as the principal platforms employed in gamified apps, with each platform utilized eight times (Table 3.2). The predominant combination employed is mobile and tablets, with 5 instances (33.3%) of multi-platform gamified applications. Personal computers have been integrated with the Web, Tablet, and VR platforms on three occasions. [De Fino et al. \(2023\)](#) utilized three platforms: personal computers, tablets, and virtual reality, in their study. Their gamified program features two modes: non-immersive and immersive.

The non-immersive option utilizes a mouse and keyboard for managing the 360-degree game view. Non-immersive games represent the optimal selection for applications requiring cost-benefit optimization. Non-immersive games provide various advantages regarding their applications, primarily due to their user-friendly nature across diverse user groups ([Feizizadeh et al., 2023](#)). Conversely, immersive game applications can improve the realism of virtual experiences, resulting in a more engaging response from participants and addressing the shortcomings of non-immersive games ([D'Amico et al., 2022](#)).

[Piangiamore and Maramai \(2022\)](#) developed an online gamified application in response to the COVID-19 pandemic, aimed at offering an interactive exercise to address the difficulties encountered by students and teachers in remote learning environments. They employed mobile devices and tablets as the platform because of their user-friendly characteristics and accessibility. Web platforms necessitate internet connectivity, yet they can be utilized on browsers without requiring prior installations. This facilitates convenience for children, as they are not required to confront any technological challenges ([Musacchio et al., 2015](#)). Web-based gamified applications

enable multi-player activities, including tournaments, through server hosting (Teague et al., 2020). This feature allows players or teams to synchronize in real-time without requiring a specific command or website refresh (Yiannakoulias et al., 2019). Despite being categorized as a web platform, access is limited to personal computers or mobile devices.

Table 3.2

Gamified applications that used multiple platforms

User Category	Used Platform						Source
	PC	Mobile	Tablet	Web	AR	VR	
Disaster Detector			✗	✗			Kankanamge, et al. (2020b)
Flood Disaster Prevention Simulation	✗		✗				Matsuno, et al (2020)
Earth Girl Volcano	✗	✗					Kerlow, et al (2020)
Earth Girl	✗			✗			Kerlow, et al (2020)
Flash Flood!	✗					✗	Skinner (2020)
Flood Action VR		✗				✗	Sermet & Demir (2019)
Decision Game	✗			✗			Yiannakoulias, et al. (2019)
Scenario-based and game-based GIS Application	✗	✗	✗				Feizizadeh, et al. (2023)
AEOLIAN AR		✗			✗		Michalis, et al. (2023)
Treme-treme	✗			✗			Musacchio, et al. (2015)
Prototype for VR-SG training in multi-hazard scenarios	✗		✗			✗	De Fino, et al. (2023)
Salvina and the Earthquake: What Will She Do?		✗	✗				Piangiamore and Maramai (2022)
Salvina and the Flood: What Will She Do?		✗	✗				Piangiamore and Maramai (2022)
Salvina and the Environment: What Will She Do?		✗	✗				Piangiamore and Maramai (2022)
Let's free Salvina!, an online. Escape Room to elude natural risks		✗	✗				Piangiamore and Maramai (2022)

The use of VR creates a positive and engaging experience for the user. Additionally, it will effectively attract a broader demographic, particularly individuals under the age of 35, to encourage active participation (Molan & Weber, 2021). The VR gamified application developed by Skinner (2020) achieved joint third place among 40 exhibits and events in the "Into the Blue" exhibition, as determined by a public vote for the most popular stand. This indicates that it serves as an effective platform for attracting

and engaging individuals. Participants recognized the effectiveness of the VR experience in enhancing the recall of disaster tips (Molan & Weber, 2021). However, the use of virtual reality (VR) can induce symptoms such as nausea or dizziness, commonly known as cybersickness, which resembles motion sickness. Moreover, virtual reality may result in headaches and eyestrain (Skinner, 2020).

- Game development paradigm

The game development life cycle (Sucipto et al., 2023), ADDIE development paradigm (Wahyudi & Hidayatullah, 2022; Zaini et al., 2020), waterfall process development paradigm (Rosyada et al., 2023), stage narrative development paradigm (Kerlow et al., 2020), design thinking model (Olivares-Rodríguez et al., 2022), and agile software development paradigm (Sermet et al., 2020; Rodavia et al., 2018; Caballero & Niguidula, 2018) represent several development paradigms utilized in these studies. Despite the differences in terminology, these paradigms adhere to comparable procedures. The actions undertaken can be categorized into four distinct phases: initiation, production, testing, and release (Table 3.3).

A comprehensive analysis of user demands, target group, software requirements, and relevant literature has been conducted during the initiation stage. In the production stage, tasks include planning application development, explaining the product to be produced, and creating an activity schedule. This stage includes the development of prototypes, creation of assets, programming, refinement of details, addition of new features, performance enhancement, and bug fixing. In the testing phase, internal testing is conducted with experts and game developers, whereas external testing includes participation from the public, target demographics, and other third parties. The results of testing include issue reports and user feedback. Upon completion of the development process, game development reaches its final stage and is ready for public release. The release stage encompasses activities such as launching the product, project documentation, information dissemination, post-mortem analysis, and planning for game maintenance and extension.

In a few studies, researchers have utilized similar methodologies, yet they failed to assign a specific designation to that paradigm (Le Dé et al., 2021; Breuer et al., 2014; Arinta et al., 2020). The majority of procedures within the examined paradigms focus on the initiation and production stages. The developers prioritize the initial phases of

game development with full focus. However, there has been insufficient emphasis on the phases that follow the completion of game development.

Table 3.3

Game development paradigms

Paradigm	Steps related to the paradigms			
	Initiation	Production	Testing	Release
Game development life cycle	Initiation	Pre-production, Production	Testing, Beta	Release
ADDIE development paradigm	Analysis	Design, Development	Implementation	Evaluation
Waterfall process development	Communication	Planning, Modelling, Construction	Deployment	
Stage narrative development	Show and tell, Target audience	Technology platform, Game format, Game prototype	Quality and user testing	Interdisciplinary collaboration
Design thinking model	Empathy, Definition, Generation of ideas	Prototyping	Evaluation	
Agile software development	Requirement gathering, Planning	Development	Testing	Maintenance, Deployment

- Software

A limited number of studies on the examined gamified application provided information about the software used in the game development process. The software has been employed for game development, asset design, coding, data analysis, and spatial configurations (Figure 3.6).

16 studies have examined the use of software in the development of game environments. Of the studies examined, 11 (68.75%) employed the Unity 3D Engine for game development (Figure 3.7). The Construct engine has been employed in two distinct studies by [Zaini et al. \(2020\)](#) and [Rosyada et al. \(2023\)](#) (Figure 3.7). The game production process employed Unreal Engine, Genially, and Kodular once ([De Fino et al., 2023](#); [Piangiamore & Maramai, 2022](#); [Rosyada et al., 2023](#)). Construct, Kodular, and Genially were used to create 2D gamified applications, whereas Unity 3D and

Unreal engines were employed for the development of 3D and VR gamified applications.

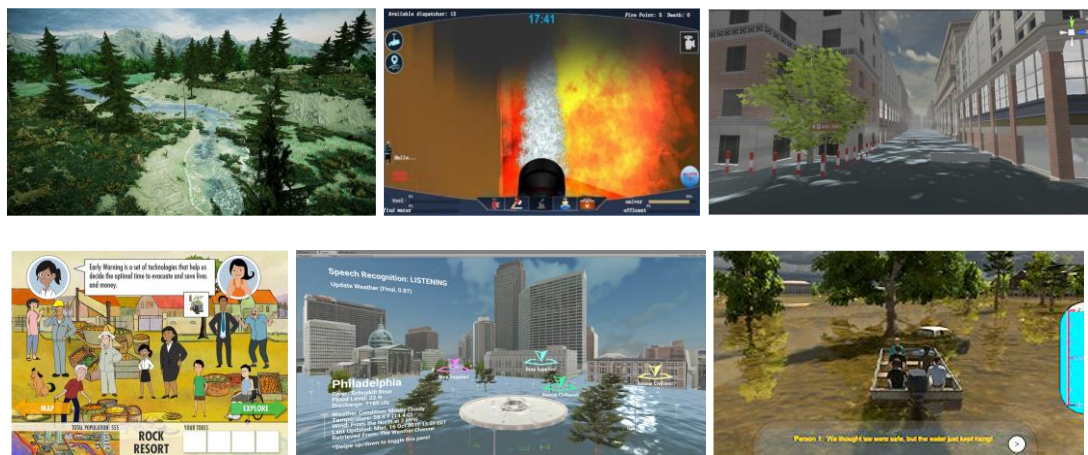
Figure 3.6

Software used in gamified application development

Game development	Asset design	Coding	Data Analysis	Spatial Configuration
Unity 3D	Autodesk Revit	Visual Studio	IBM SPSS	ArcGIS
Construct 2	Adobe Photoshop	MySQL	NVIVO	City Engine
Unreal Engine	Adobe Illustrator		Atlas TI	Google Maps Platform
Genially	Blender		Google Analytics	GAMA
Kodular	Maximo			
	Bitmoji			

Figure 3.7

Interfaces of gamified applications developed by Unity 3D



Note. Figures left to right from top : (1) “Flash Flood!” Vol.2 (Skinner, 2020), (2) “Fire Drill Game” (Jiang & Hu, 2021), (3) Non-immersive VR SG (D'Amico et al., 2022), (4) “Earth Girl Volcano” (Kerlow et al., 2020), (5) “Flood Action VR” (Sermet & Demir, 2019) and (6) “Project Lily Pad” (Tomaszewski et al., 2020)

Unity3D is extensively utilized by educators in the education sector to develop educational games and improve learning outcomes in the classroom, thereby enhancing students' learning efficiency (Jiang & Hu, 2021). Skinner (2020) found that participants who engaged with the “Flash Flood!” gamified application perceived the experience as realistic. D'Amico et al. (2022) reported that 87% of participants were

satisfied with the realism of the virtual world in their gamified application, and 85% deemed the flood scenario sufficiently realistic. Fifty-four percent of participants perceive the interaction with non-player characters (NPCs) in the serious game (SG) as adequately realistic

Figure 3.8

Interfaces of gamified application developed by Unreal and Construct Engine

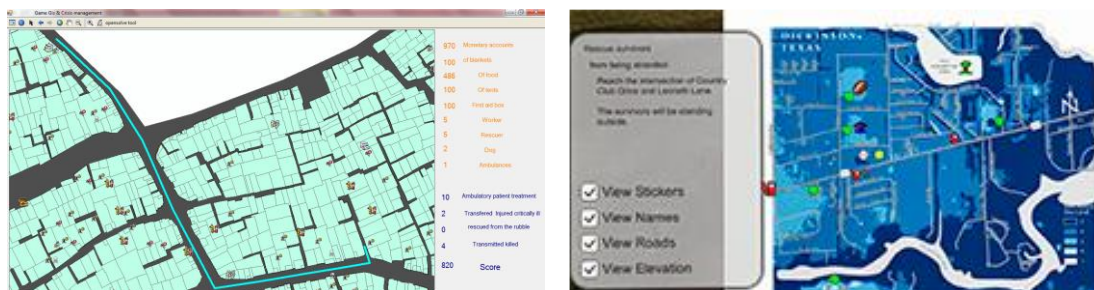


Note. Figures left to right : (1) Prototype for VR-SG training (De Fino et al., 2023) and (2) “Bahaya Air” (Zaini et al., 2020)

The primarily 3D elements were created utilizing Blender and Autodesk Revit. Furthermore, specific gamified applications developed with the Unity 3D engine using the Unity Asset Store to acquire essential game assets (D'Amico et al., 2022). Researchers employed various software for coding and data processing, customized to their specific requirements. For instance, gamified applications developed with the Unity 3D engine require Visual Studio for C# programming (D'Amico et al., 2022). Developers integrated multiple GIS applications into the game to display spatial arrangements in gamified applications (Figure 3.9 and Figure 3.10).

Figure 3.9

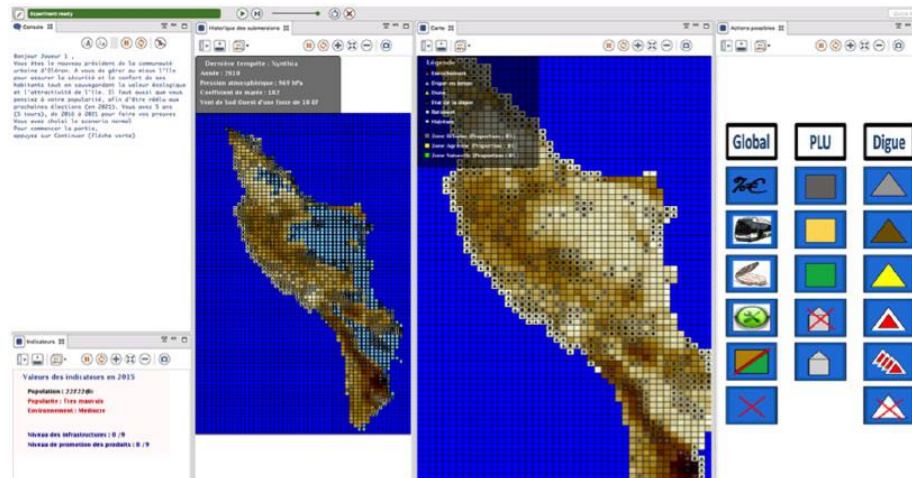
Use of GIS in gamified application incorporating ArcGIS



Note. Figures left to right : (1) Scenario-based and Game-based GIS Application (Feizizadeh et al., 2023) and (2) “Project Lily Pad” (Tomaszewski et al., 2020)

Figure 3.10

Use of GIS in gamified application incorporating GAMA



Note. “SPRITE” (Taillandier & Adam, 2018)

Tomaszewski et al. (2020) investigated effective methods for designing serious games that incorporate spatial thinking, GIS tools, and visual representations to improve disaster resilience. 90% of the study group reported no prior experience with spatial thinking. After playing the game, 50% of participants indicated that it enhanced their awareness of their spatial navigation. The incorporation of spatial configurations has significantly impacted participants using these gamified applications.

3.1.4 Strategies used for testing and launching the application

- Internal and External testing

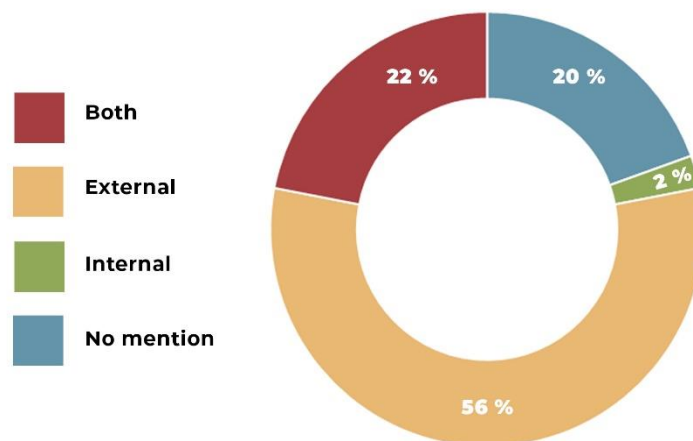
Two types of testing were conducted regarding the reviewed gamified applications (Figure 3.11). Internal testing was conducted to evaluate operational functionality and gameplay capabilities. Upon completion of the modifications, external testing is performed, providing the tester with increased flexibility to engage with the game. The main aim is to gather feedback regarding the quality criterion of entertainment and usability (Sucipto et al., 2023).

The internal testing is primarily carried out by a team of experts, including professors, researchers, PhD candidates, and emergency management professionals. The experts offer technical commentary on the simulation (D'Amico et al., 2022; Tomaszewski et al., 2020). Key project stakeholders are essential for the development of co-design (Olivares-Rodríguez et al., 2022). Additionally, fostering open dialogue and

discussion between scientists and artists is crucial when creating games focused on disaster preparedness and response (Kerlow et al., 2020). Le Dé et al. (2021) employed a participatory approach that enabled children to co-design, implement, and evaluate the initiative. The involvement of teachers in session design was essential for ensuring curriculum alignment, anticipating challenges, and identifying authentic participation opportunities, as they possessed the best understanding of their students.

Figure 3.11

Use of different type of testing in the reviewed gamified applications



In total, 76% of the studies incorporated external testing performed by third-party groups, including students and teachers (Piangiamore & Maramai, 2022), the general public (Rebolledo-Mendez et al., 2009), or through assessments conducted at specific venues and exhibitions (Gampell et al., 2021; Skinner, 2020). Among the studies analyzed, 65.8% employed formal external testing, utilizing either pre-test and post-test questionnaires (29.2%) or solely post-test assessments (36.6%). One study utilized focus group discussions for external evaluation (Le Dé et al., 2021), whereas another study employed A/B testing for evaluation (Caballero & Niguidula, 2018). Some external testing did not evaluate the gamified application directly; instead, it concentrated on assessing the learning outcomes and performance of the participants. The assessment of their performance involved the use of game mechanics, including scores and metrics, alongside game screen recording and sensors (Ardiadna & Setiawan, 2023; Jiang & Hu, 2021; Rebolledo-Mendez et al., 2009). Sermet and Demir (2019) utilized voice input to analyze users' vocal patterns and their reactions to incidents, aiming to identify emotional and psychological states.

[Arinta et al. \(2020\)](#) employed the USE testing method to assess the prototype for external testing. This method entailed posing questions to evaluate the prototype's usefulness, satisfaction, and ease of use. [Skinner \(2020\)](#) examined the dimensions of enjoyment, learning, preferred activities, and visual content within the gamified application. Additionally, he utilized autonomous methods for participants to offer feedback, such as graffiti walls and feedback cards.

- Use of social media and promotions

Gamified applications employ social media and promotional campaigns to increase their popularity among children and the broader public. A YouTube channel has been created to support the activities of the “Flash Flood!” game. This channel presents videos that demonstrate the game and offer a comprehensive overview of the virtual reality experience ([Skinner, 2020](#)). The “Flash Flood!” handout was employed in the NERC UnEarthed Science Showcase to enhance the exercise, guiding participants to the “Flash Flood!” 360 movie. In 2019, more than 10,000 views were documented for all the videos ([Skinner, 2020](#)). A Facebook page has been created to disseminate the educational game "Treme-Treme" and to offer information regarding earthquake risk and preparedness. The page currently has more than 400 followers ([Musacchio et al., 2015](#)). The game "FloodSim" was marketed via various websites and magazines before its public release ([Rebolledo-Mendez et al., 2009](#)). [Fernández and Ceacero-Moreno \(2021\)](#) uploaded simulation footage of the gamified application "Cities: Skylines" to their YouTube channel to promote the application.

Figure 3.12

Use Promotional activities of “Earth Girl” Series



Note. Source from (Kerlow, 2014)

The "Earth Girl" game series, which includes "Earth Girl," "Earth Girl 2," and "Earth Girl Volcano," utilized CD giveaway packs as a promotional strategy, offering stickers, posters, and T-shirts as incentives (Figure 3.12). Packs were distributed during geography lessons at multiple elementary and middle schools, where the game

was demonstrated (Kerlow et al., 2020). An online event is organized to introduce the game "Salvina and the Flood: What Will She Do?" to players, featuring the publication of a promotional poster for a special location. The promotional material for the "Let's Free Salvina!" Escape Room, an online game simulating escape from natural hazards, was featured at the 9th Planet Earth Week. A poster entitled "Salvina and the Environment: What Will She Do?" was presented at the European Researchers' Night 2021. The poster emphasized the promotion of eco-friendly behaviors and was accessible for online viewing (Piangiamore & Maramai, 2022).

In contrast, Gampell et al. (2021) describe how their promotional strategies hindered participant engagement in the "Quake Safe House (QSH)" gamified application. The placement of the QSH display in the museum inadequately facilitated visitor engagement with the messages of disaster. Improving game mechanics and increasing player motivation are essential for enhancing player engagement.

- Launch and accessibility

Out of the applications reviewed, 12 are available for download or online play on their respective websites. Numerous gamified applications have been launched; however, they are currently inaccessible to the public. The mobile game "Sai Fah - The Flood Fighter" was released on the App Store and Play Store; however, it is currently unavailable (Kankanamge et al., 2020b). Additionally, "Earth Girl Volcano" and "Earth Girl 2" have been released on the Play Store and App Store; however, they are presently inaccessible. The PC version of the game is available to the general public (Kerlow et al., 2020; Gampell et al., 2020). Some gamified applications remain in the prototype phase, indicating that the game has not yet been made available to the public (De Fino et al., 2023). The current gamified applications, exemplified by "Stop Disasters!", maintain a contemporary website that provides regular updates on their activities and game enhancements (UNDRR, 2024). The "Earth Girl" game series and "HurricaneLog" game maintain a website that provides information regarding their activities and recent releases to the public (Kerlow, 2024; Pereira et al., 2022).

The published papers (Tsai et al., 2020; D'Amico et al., 2022; Zaini et al., 2020; Rosyada et al., 2023; Molan & Weber, 2021) do not address the launch or current availability of gamified applications. The current state of gamified applications was examined through online research and analysis of social media channels (Kankanamge

et al., 2019; Kankanamge et al., 2020a). Nonetheless, no particular information was acquired. These applications are mainly limited to research purposes and have not achieved significant recognition as popular applications.

The authors of the published study were contacted via email to obtain information regarding the release and current availability of these apps. The research team behind the "HurricaneLog" gamified application has released further details regarding their successful launch. Thiago Pereira, the primary author, indicated that the game was integrated into designated university courses. This approach encouraged student engagement and provided a practical learning experience. They will prioritize the development of research directions focused on player strategies and in-game actions as part of their future objectives.

The research team of "Flood Action VR" has also provided a response to us. Yusuf Sermet, the primary author, articulated that the strategies for launching the application involved the early involvement of educators, disaster management experts, and the general public to collect feedback and ensure the application aligns with user requirements. Furthermore, partnerships with relevant institutions and organizations were employed to improve credibility and broaden outreach efforts. Their future plans include the integration of conversational AI, such as ChatGPT, and machine learning to improve training experiences and provide real-time insights. They also seek to adapt the program for different geographic regions and languages to enhance its accessibility and effectiveness.

Isaac Kerlow, the creator of "Earth Girl Volcano," noted collaboration with various civil protection agencies, particularly in Southeast Asia. They engaged with communities in high-risk areas of Indonesia and the Philippines to implement their launch plans. Mónica Ferreira, the creator of the game "Treme-Treme," disclosed that the game has been highlighted in the fun games and educational apps sections of various Portuguese publications focused on children's activities, including *Estrelas e Ouriços*. The game has been chosen as one of the activities at the Quake Museum – Lisbon Earthquake Centre. These factors have been significant in the successful launch of the game. No responses have been received from the emails sent to other authors and developers of gamified applications.

3.1.5 Challenges in use of gamified application in disaster education

The necessity of internet access to utilize gamified applications for disaster education presents a significant challenge. [Rodavia et al. \(2018\)](#) developed a web-based application for a region characterized by limited internet connectivity. The developers limited the utilization of bandwidth-intensive assets and materials, including flash and animated content, within the gamified application to mitigate this issue. Virtual reality (VR) and immersive gamified applications require expensive equipment, such as head-mounted displays, which can be prohibitively costly to acquire multiple times. Therefore, the immersive experience is not fully realized. [Skinner \(2020\)](#) created a desktop-exclusive version of the VR application, which was made publicly available on SourceForge. This version allows users to control it with a mouse and keyboard. Yusuf Sermet, the developer of the "Flood Action VR" application, conveyed significant insights through email correspondence. The challenges in developing the application include ensuring compatibility across various platforms, designing an intuitive and realistic user interface, and maintaining high performance during the rendering of complex 3D environments.

Numerous gamified applications are developed in languages other than English ([Piangiamore & Maramai, 2022](#); [Zaini et al., 2020](#); [Gampell et al., 2021](#)). As a result, they are solely accessible to gamers who are proficient in the native language. Consequently, applications incorporating gamification features have diminished global interest and adoption within educational institutions and curricula. The availability of games in suitable languages is essential for their potential success ([Kerlow et al., 2020](#)). Gamified applications are anticipated to be translated into English and other alternative languages ([Piangiamore & Maramai, 2022](#); [Gampell et al., 2021](#)). [Sermet and Demir \(2019\)](#) identified the integration of natural language processing for voice commands and the facilitation of cross-platform support as significant challenges in the development of the gamified application.

The central issue lies in assessing whether the intended learning outcomes of the gamified application have been successfully conveyed to the participants. [Kerlow et al. \(2020\)](#) examined the challenges in convincing scientists of their methodology for developing an engaging game for the target audience. Although gamified applications incorporate elements that promote public engagement, it remains unclear whether participants effectively gain knowledge pertaining to disaster awareness. The study by

Winarni & Purwandari (2018) indicates that the main goal of learning is not the acquisition of extensive new information, but the cultivation of skills necessary to investigate important issues and foster independent learning. Molan and Weber (2021) do not claim that their VR gamified application addresses the critical issue of bushfire preparedness. They assert that the use of VR may result in significant enhancements, including assisting individuals in recalling bushfire guidelines.

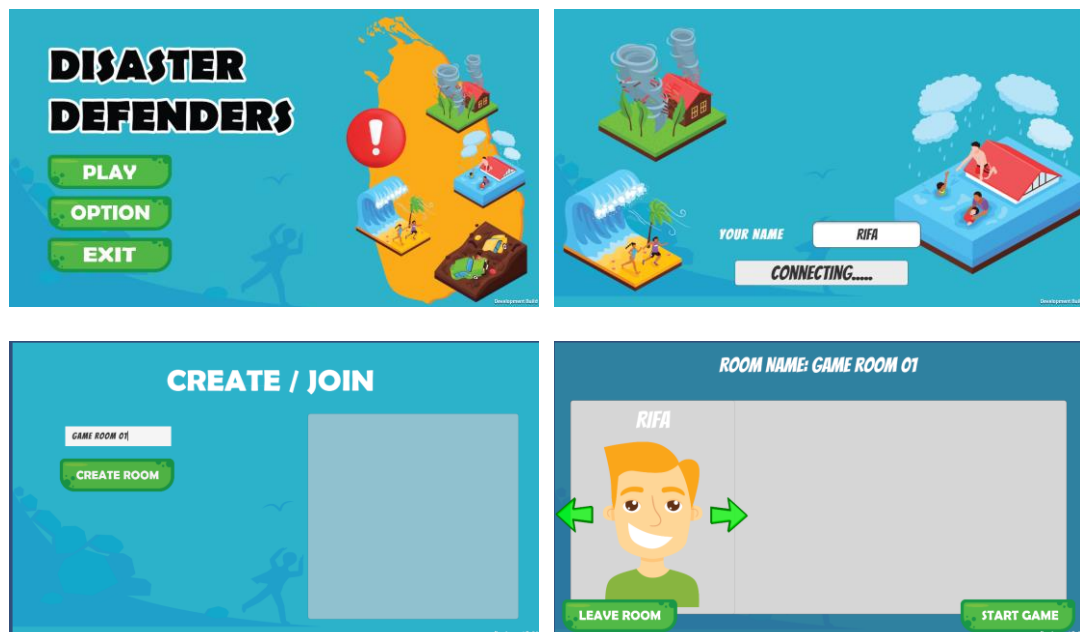
3.2 Phase 02 – Development of Gamified Application

3.2.1 Game development

In Figure 3.13, selecting “play” directs the player to the subsequent screen, where they are required to enter their name and connect to the multiplayer server. The user has the option to create or join a room established by a server in the subsequent screen. Upon selecting a room, the lobby screen will be displayed, allowing players to await the arrival of others. Players have the option to select an avatar and engage in the lobby. Pressing "start game" directs players to the gameplay interface, where they are required to choose their scenes to construct and protect their neighborhood from flooding.

Figure 3.13

Game screens of “Disaster Defenders” gamified application



Note. Figures left to right from top: (1) Main Menu Interface, (2) Server Login Interface, (3) Room Create / Join Interface and (4) Lobby Screen Interface

Upon pressing the start game button, players are prompted to select elements necessary for constructing their own neighborhood, including both natural and manmade components (Figure 3.14).

Figure 3.14

Selection of elements for gameplay



The layout selection aims to enhance players' cognitive skills by prompting them to reflect on the appearance of their hometowns. This analysis reveals (1) children's perceptions of their town and neighborhood and (2) what features they consider essential for a community. Figure 3.16 illustrates the architecture, flow, and layout selection process of the complete gamified application.

The game user interface has been modified in response to received feedback. The initial gaming interface underwent testing with participants from EXMO 2023. Figure 3.15 illustrates the enhancement of the user interface through comments and recommendations. The assessment was conducted again for grade 6 students at C.W.W. Kannangara Central College in Mathugama, Sri Lanka.

Figure 3.15

Improvements to Game Interface



Note. Figures left to right : (1) Game Interface at EXMO and (2) Game Interface at C.W.W Kannangara College, Mathugama

Figure 3.16

Game Architecture of Disaster Defenders

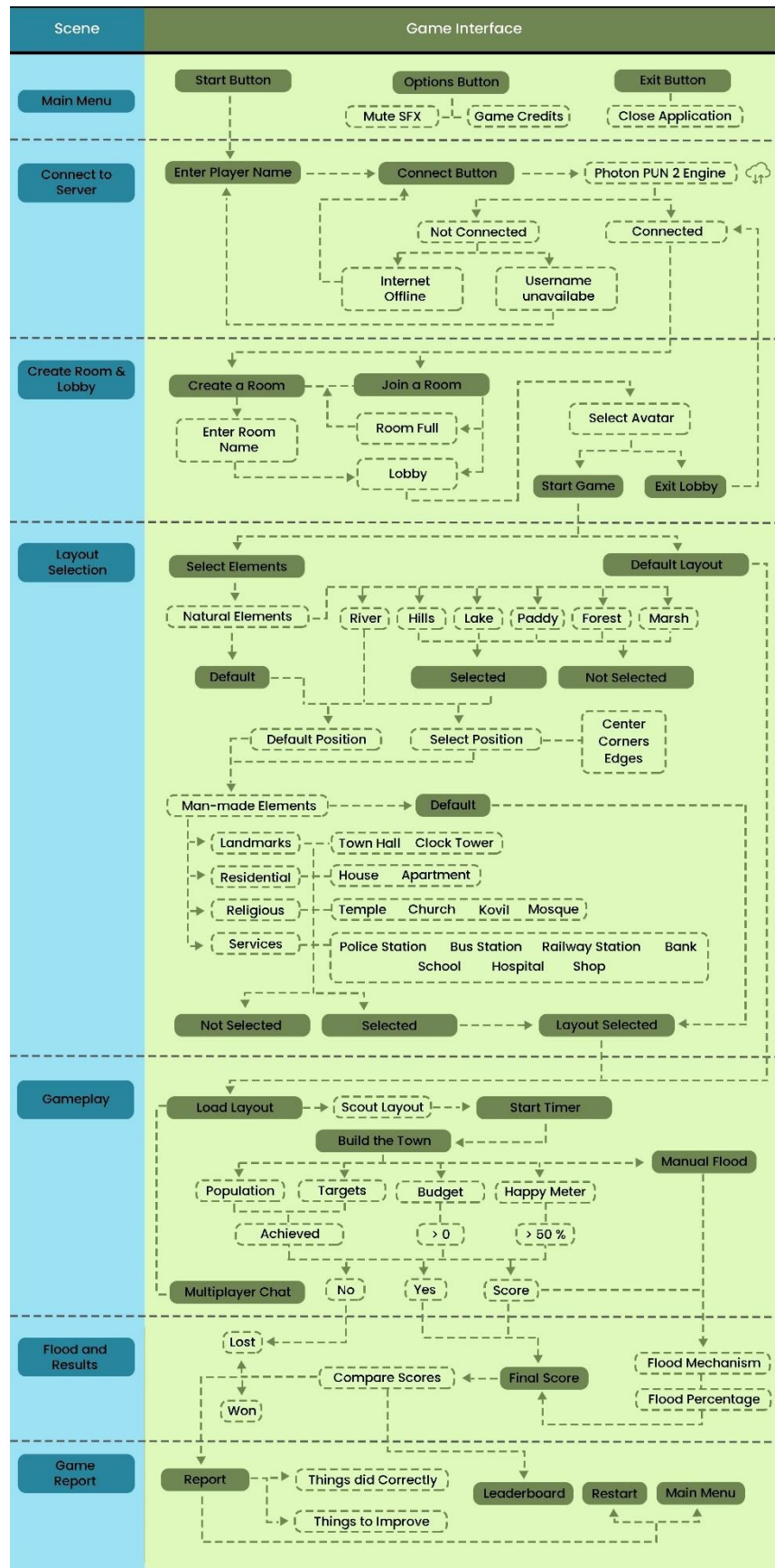


Figure 3.17 presents seven building options, with the remaining time displayed on the screen. When this time is less than one minute, it is indicated in red (Figure 3.18). A warning message will be displayed after the timer expires, prior to the onset of the flood.

Figure 3.17

Current updated Gameplay Interface

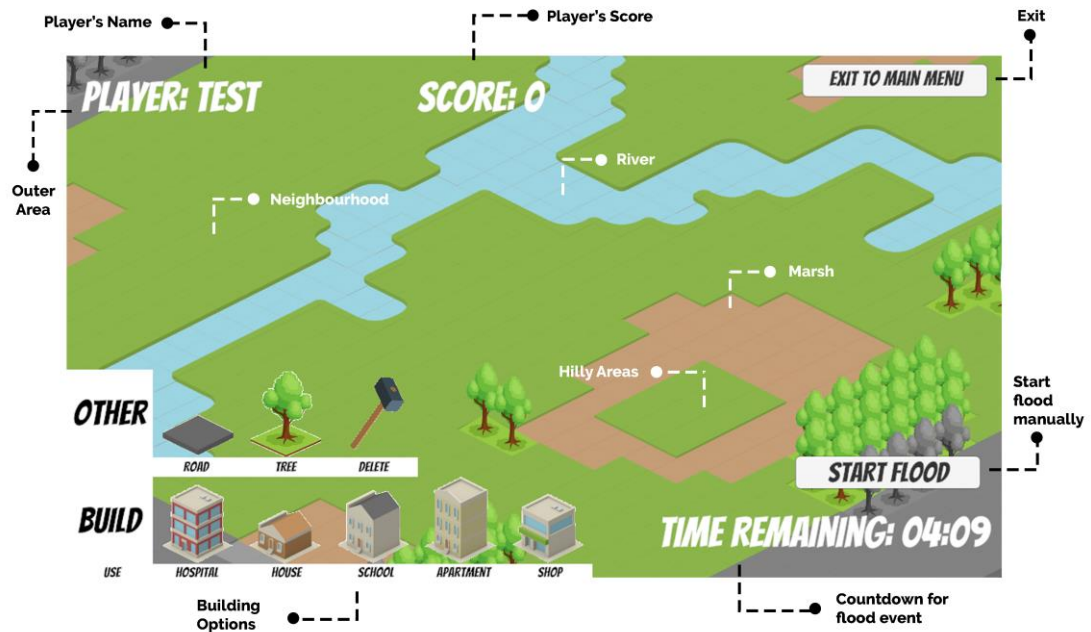


Figure 3.18

Time mechanics



The player is required to develop the neighborhood within a specified timeframe; otherwise, the player has the option to initiate the flood by pressing the start flood button once the neighborhood is prepared to confront the impending disaster. The flooded tiles will be distinctly identified by highlighting them in red. Figure 3.19 illustrates that flooding events lead to changes that differ based on the type of tile involved. Subsequent to the flood, the screen (Figure 3.20) will display the final score and the percentage of flood damage, allowing for the determination of the winner through score comparison.

Figure 3.19

Buildings before and after the flood

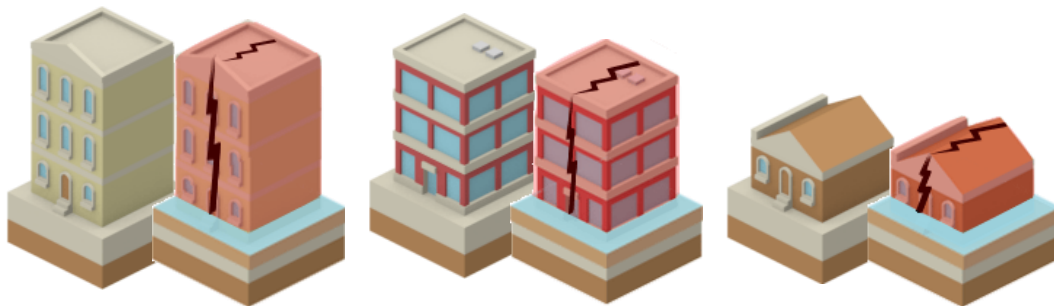
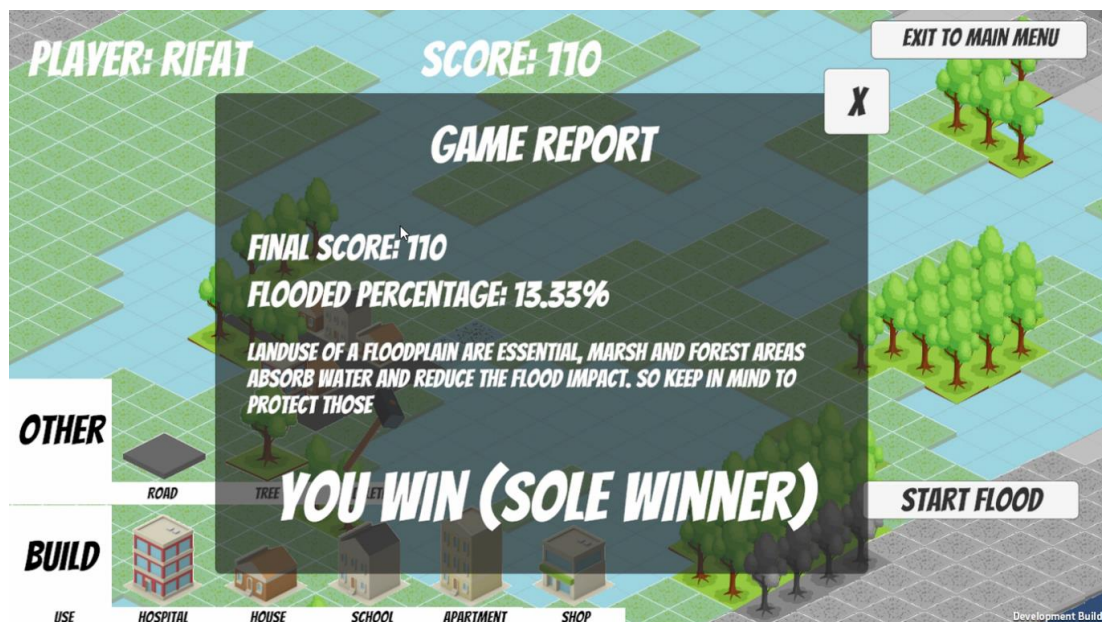


Figure 3.20

Game Report



3.2.2 Testing 01 – EXMO 2023 University of Moratuwa

Initial testing was carried out at “EXMO 2023 - The flagship Technological Exhibition” held at the University of Moratuwa, Sri Lanka. Participants were presented with the gamified application, engaging in play and learning activities. Participants for data collection were selected based on their interest in the Disaster Defenders game display, rather than inviting all exhibition visitors to participate. The researcher sought participation in the study from visitors who approached Disaster Defenders. Participation in the Disaster Defenders game exhibit was the sole means by which individuals were exposed to the game prior to the trial. [Gampell et al. \(2020\)](#) employed a comparable method to select players from the museum for the Quake Safe House

game. The stall featured an appealing design that motivated participants to engage with the game. A brief video showcasing the game was presented at the front of the stall. Over 125 players participated, and more than 500 individuals understood its concept. The exhibition was held at university facilities from July 27 to 29, 2023.

The testing comprised five steps: (i) introductory briefing, (ii) pre-test questionnaire, (iii) game play, (iv) game report briefing, and (v) post-test questionnaire. This method was employed in Kolb's experiential learning cycle, which adhered to a comparable process but included additional iterations (Tsai et al., 2020; Kankanamge et al., 2022).

- Introductory Briefing

Figure 3.21

Introductory briefing at EXMO 2023



The introductory briefing aimed to deliver fundamental information regarding the game (Figure 3.21). During the testing phase, the game was still in development; therefore, we informed them of potential flaws and bugs that would necessitate their assistance for resolution.

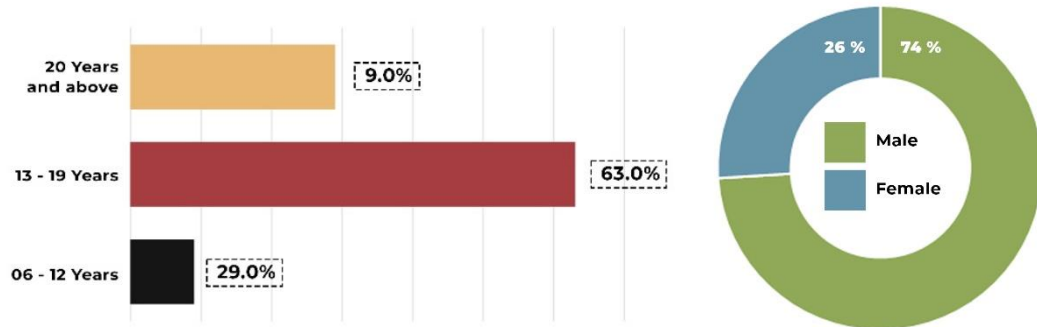
- Pre-test questionnaire

The pre-test questionnaire comprised three sections: (i) General Information, (ii) Gaming Behavior, and (iii) Gamification. The collected basic information comprises the participant's name, age, gender, and residence. The testing did not primarily concentrate on the specified target demographic, which consisted of children aged 6 to 12. All attendees of the exhibition were invited to participate freely and without restrictions. The “Disaster Defenders” gamified application was specifically designed for children aged 6 to 12, ensuring that its design and functions are appropriately

aligned with their needs. The majority of participants were aged 13 to 19, with 28% of game players within the targeted age range. The majority of participants were male individuals residing in and around Colombo (Figure 3.22).

Figure 3.22

Age and Gender of the Participants

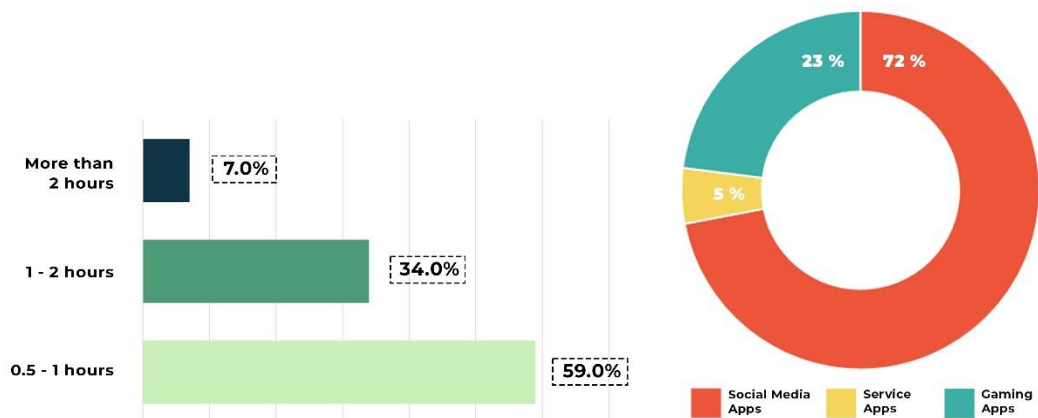


The subsequent section of the questionnaire included three closed-ended questions aimed at elucidating players' gaming behavior, specifically regarding the applications they utilize most frequently, their interest in gaming, and the number of hours they engage in gameplay daily.

Many participants utilize social media applications, including Facebook, Instagram, and YouTube, while 23% frequently engage with gaming applications. Over 80% of participants expressed an interest in gaming, while others exhibited only a marginal interest. 59% of participants engage in gaming for less than one hour daily, while only 2% exceed two hours. This suggests that participants possess fundamental gaming knowledge, despite a lack of deep interest.

Figure 3.23

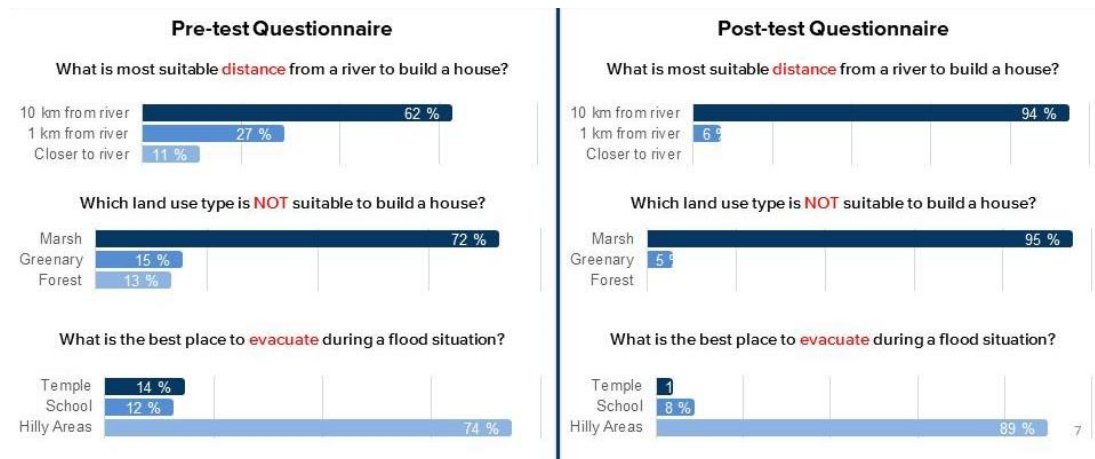
Game playing time per day and Apps used by Participants



Subsequently, three closed-ended questions regarding flood awareness and gamification were posed (Figure 3.24). These included inquiries about the optimal distance from a river for house construction, the land use type unsuitable for building a house, and the most effective location for evacuation during a flood scenario.

Figure 3.24

Feedback of pre and post-test questionnaire by participants



- Gameplay

After completing the pre-test questionnaire, participants were allotted 5 minutes to engage with the game. Participants collaborated with a support person to gain familiarity with the tools. Physical space arrangement was designed to facilitate competition among three players facing each other (Figure 3.26).

Figure 3.25

Gaming Arrangement at EXMO 2023



- Game report briefing

Figure 3.26

Participants playing “Disaster Defenders” at EXMO 2023



After the gameplay, the support person delivered a brief analysis of the player's errors, suggested improvements for scoring, and strategies to minimize flood damage percentage. The support person explained specific principles of urban planning and disaster preparedness during that time. The player was invited to ask questions about the gameplay and its underlying concepts.

- Post-test questionnaire

The findings indicate that gamers positively influenced flood disaster education, achieving a correct response rate of 90% after gameplay (Figure 3.24). Subsequently, participants were presented with a closed-ended question regarding their learning outcomes from playing "Disaster Defenders." The majority of participants reported acquiring knowledge regarding the Facts to Consider When Building a House, Land Use Types, and Vulnerability through the game. 2% of the participants reported acquiring knowledge regarding evacuation locations during a flood situation. The findings demonstrate that participants acquired knowledge regarding flood disaster preparation and fundamental planning principles. This constitutes a positive enhancement to the game's feedback.

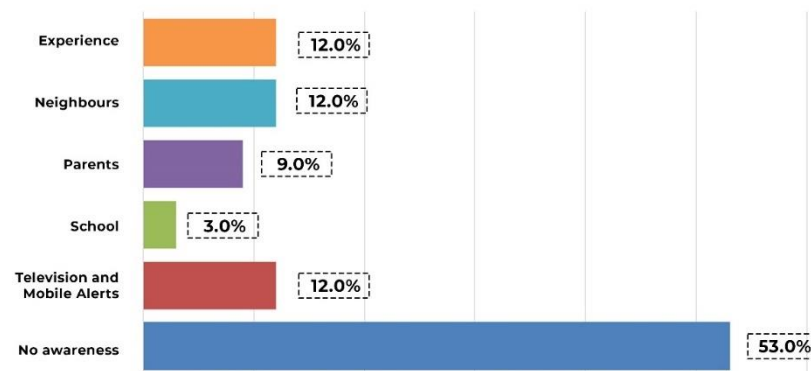
Finally, an open-ended question was posed to participants in order to get feedback on how to enhance the game. The word cloud analysis indicates that numerous participants provided positive feedback regarding the quality of the gamified application, while also emphasizing the necessity for additional improvements. Additional terms highlighted include add, sounds, remove, bugs, launch, and others. Participants emphasize the importance of incorporating sounds and eliminating bugs. Furthermore, terms such as children, buildings, background, and neighbourhood were highlighted.

- Pre-test questionnaire

The questionnaire, like the prior pre-test version, is divided into three identical sections. This study examines three primary areas: (i) General information, (ii) Gaming behaviour, and (iii) Gamification. However, the nature of the questions it included was more instructive and purposeful. The participants were asked about their familiarity and knowledge regarding a flood situation.

Figure 3.28

Sources of pre-awareness about flood



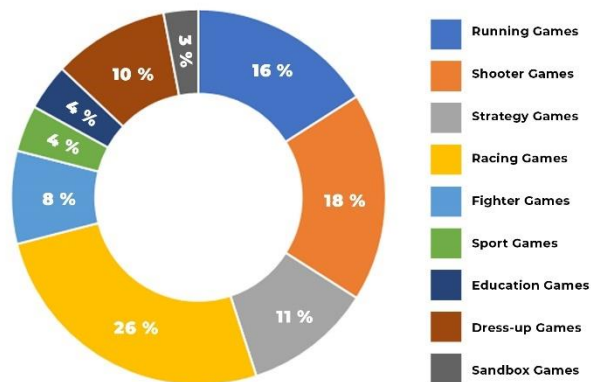
50% of the students surveyed reported experiencing a flood situation. Among this group, 53% indicated a deficiency in prior knowledge or awareness regarding floods. However, these pupils have gained awareness from various sources, including television, parental guidance, interactions with neighbors, and personal experiences. A significant proportion of students, specifically 57%, have been informed about floods via traditional media channels, including television and news outlets. In contrast, the other students obtained this information from various sources such as educational institutions, radio broadcasts, communication with parents and grandparents, newspapers, internet platforms, social media, mobile notifications, local communities, and personal acquaintances.

Following several inquiries into students' gaming behaviors, 88% reported having engaged in computer or mobile gaming. Students exhibited a preference for racing games such as Need for Speed, Asphalt, and Beach Buggy, as well as shooter games including IGI, Free Fire, and PUBG, and running games like Temple Run, Subway Surfer, and Talking Tom Gold Run. Girls engaged in Barbie Dreamhouse Adventures,

Hello Kitty games, and various dress-up games, with 4% participating in educational games (Figure 3.29).

Figure 3.29

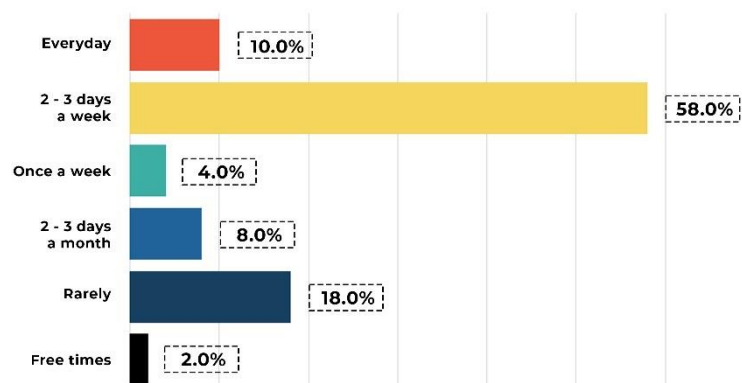
Gaming preferences by Students



58% of Students engage in gaming activities two to three times weekly (Figure 3.30), with an average duration of 47.8 minutes per session. Only 39% of students utilized educational applications such as Study Bunny, Exam Hub, Laxapathi Game, Maths Podda, and 5-Api. The attraction of racing and shooting games is driven by visually appealing interfaces, opportunities for social interaction, aspirations to enhance scores and levels, the accumulation of in-game currency, and the efficient use of leisure time following academic activities, which collectively motivate children to engage in these games. Educational games predominantly reported are utilized for preparation for the Sri Lankan grade 5 competitive national scholarship examination, a practice influenced by parental involvement.

Figure 3.30

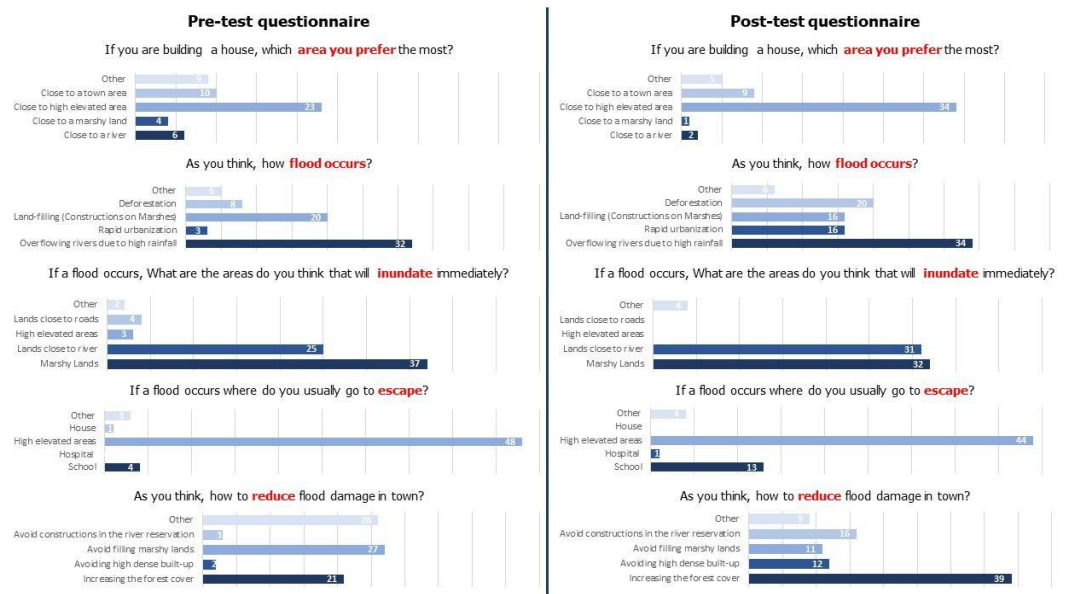
Gaming frequency by Students



A series of five semi-structured inquiries were conducted with the students regarding their flood awareness and the influence of gamification on this awareness. Students are permitted to provide multiple responses for each question. The set of five questions was included in both the pre-test and post-test questionnaires.

Figure 3.31

Summary of feedback for pre and post-test questionnaire by grade 6 students in C.W.W Kannangara Central College, Mathugama



- Gameplay

After completing the pre-test questionnaire, students were given 5 minutes to participate in the gameplay. The gamified program, unlike its predecessor, is designed solely for single-player mode, without any multiplayer connectivity.

Figure 3.32

Gameplay arrangement at C.W.W. Kannangara Central College, Mathugama



(Figure 3.34). They prioritized the strategic placement of hospitals near residential areas to improve emergency response capabilities. To mitigate potential flood damage, trees have been strategically planted near rivers. The construction of stores near residential areas has been implemented to improve the accessibility of amenities and services for residents.

The pre-post-test questionnaire inquired about students' preferences for home building locations (Figure 3.31). The responses indicate increased attentiveness following the use of the gamified application, with a 67% rise in the number of students constructing their homes in elevated regions. Excessive rainfall is widely recognized by students as a factor that leads to river overflow and subsequent flooding. Following the use of gamified applications, students acquired knowledge regarding deforestation and rapid urbanization, both of which contribute to flooding. A significant proportion of students accurately recognized immediate inundation (60.78%) and escape areas (61.76%). Post-game, inaccuracies were rectified. Students responded to inquiries regarding flood mitigation strategies, including rainwater harvesting, bridge construction, and the maintenance of drainage systems in the pre-test questionnaire. Following the utilization of gamified applications, students acquired more effective strategies for mitigating flood damage.

Figure 3.35

Word cloud prepared by feedbacks to improve the game



In conclusion, we requested student opinions regarding potential enhancements to the gamified application (Figure 3.35). A majority of students indicated a preference for including individuals and vehicles, including cars and buses. They also proposed

broadening the spectrum of building types and offering a wider array of residential options, including structures with differing story counts. A limited number of students provided feedback regarding the inclusion of natural settings, such as waterfalls and mountains, in the user interface. A small percentage of students (5.88%) have suggested extending the time duration, while a lesser percentage (3.92%) have proposed the inclusion of additional levels in the gameplay experience.

- Briefing and tutoring

Figure 3.36

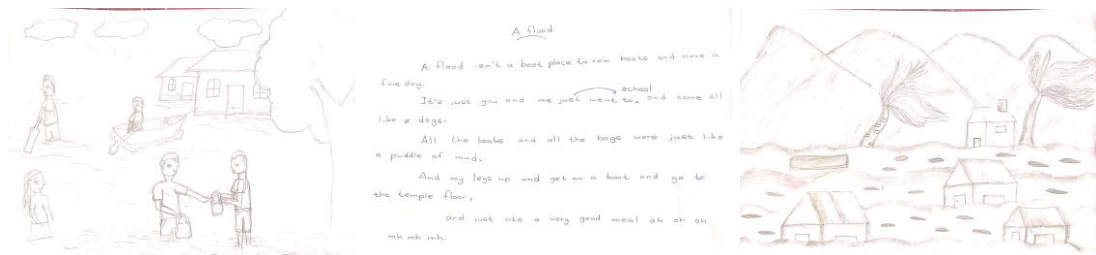
Tutoring session with students



Following the post-questionnaire, flood awareness videos were presented during a briefing and tutoring session (Figure 3.36). Students received written or artistic assignments to exhibit their understanding of floods (Figure 3.37). The team disseminated stickers and posters to students via memoranda.

Figure 3.37

Students artistic and written compositions



3.2.4 Lessons learned from testing and improvement for gamified application

During the initial testing at EXMO 2023, it was noted that children exhibit significant attentiveness during the introductory briefing, acquiring essential information prior to engaging in play. During the five testing phases, participants acquired knowledge regarding town planning and disaster management with the aid of a support individual. According to Kolb's experiential learning cycle (Tsai et al., 2020), the testing technique was nearly flawless.

Following testing, the subsequent issues were observed: (a) Several bugs and loopholes exist, particularly in hilly regions of the landscape where construction is not permitted; (b) The scoring system encountered issues in calculating building additions; (c) Additionally, minor problems such as multiplayer connectivity, score syncing and comparison, and connection issues after replay were identified and addressed in preparation for the second test examination.

Figure 3.38

Neighbourhood Plans of the participants of EXMO 2023



In the second round of testing, students received no pre-game instructions. Students were provided with a trial play before the commencement of gameplay. Subsequently, the students participated in the gamified application and the briefing session that followed the post-test questionnaire. This approach enabled the assessment of students' awareness of flood disasters through the use of a gamified application.

Figure 3.39

Neighbourhood Plans of the students of C.W.W Kannangara Central College, Mathugama



In the second testing, students indicated the need to (a) add a tool for removing erroneously added buildings. Some individuals indicated the (b) possibility of constructing elements beyond the designated building area, while others requested the (c) inclusion of sound elements. Additionally, students indicated a desire to (d) increase the number of building options. The suggestions have been incorporated into the final gamified application (Figure 3.17). An eraser tool has been incorporated into the gamified application, with the outer areas greyed out, preventing players from constructing anything in those regions. Players are also prohibited from constructing anything on water bodies. The sound elements have been incorporated for background and visual effects.

Disaster education has been integrated into the school curriculum in Sri Lanka, specifically aimed at students aged 12 and older ([Educational Publications Department, 2023](#)). The survey indicates that children under the age of 12 lack sufficient disaster education, relying primarily on information from news and other publicly available sources. They may have participated in several workshops organized by Non-Governmental Organizations, if fortunate. However, it is highly uncommon. This gamified program enables children under 12 to explore the vulnerability to flood disasters.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

Disaster education in Sri Lanka has traditionally employed a conventional approach, characterized by the transmission of concepts to students with minimal engagement or experiential learning. Consequently, it is essential for students to acquire practical experience, fundamental skills, and enhance their self-awareness and civic responsibility concerning disaster prevention and mitigation. This study developed a serious game for disaster education through the integration of game-based learning. The Disaster Defenders game was developed to educate children aged 6 to 12 on flood disaster preparedness and mitigation. Given that children cannot learn about disasters through empirical methods, gamification has been employed to sustain their interest in the learning outcomes.

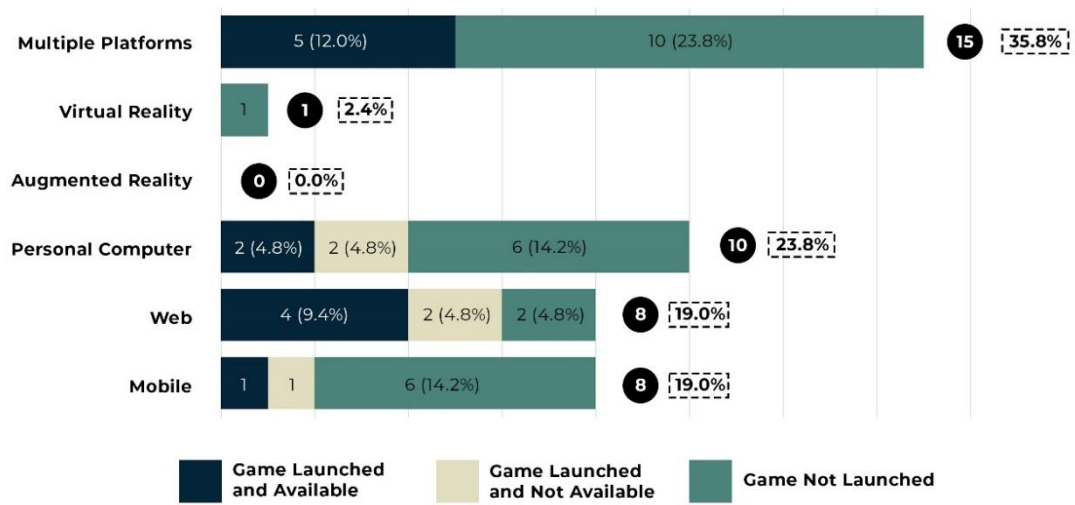
A variety of gamified applications have been created in the literature to enhance disaster awareness and education. This study analyzes 42 gamified applications and highlights their various potentials in educating children, youth, and the general public. This study aims to examine the technological components and strategies utilized by a gamified application for a successful game launch in disaster education.

4.1 Key design elements and characteristics that enhance the efficacy of a gamified application in educating children and youth about flood disaster

In this study, 42.8% of applications were developed for personal computers, offering a moderate level of immersion relative to virtual reality (VR) applications. Prolonged use of virtual reality negatively impacts players, and the high cost of related equipment hinders the platform's broad adoption. Mobile and tablet platforms are frequently employed due to their enhanced accessibility. The web platform offers convenience when the internet is accessible, as it can be utilized through a browser without requiring any installations.

Figure 4.1

Development platforms and Availability



Of the applications evaluated, 59.5% have either not been launched or do not intend to launch post-development. At present, 28.5% of gamified applications are accessible for play. Most of these applications (12%) are developed across multiple platforms, whereas 9.4% are designed exclusively for the web. Among all applications available across various platforms, 4.8% are also associated with web-based platforms. The web is the most successful platform that has emerged following the development of games. Furthermore, 12% of applications were initiated but later became inaccessible due to reasons such as discontinuation or insufficient support for platforms like Flash Player.

Asian countries accounted for the majority (32.4%) of the reviewed gamified applications; however, only a small fraction (2.4%) is specifically available and developed for a web platform. Another game that has been successfully launched from Asia is "Sai Fah - The Flood Fighter," which was produced in the Philippines for mobile platforms. The game is presently unavailable in the app store and play store. Consequently, Asian developers have not emphasized web-based platforms, resulting in a less successful game development launch. In contrast, developers from Europe, America, and Australia have effectively deployed the gamified application across various web and multiple platforms. It is clear that numerous Asian gamified applications were mainly developed for research objectives, overlooking post-development strategies.

In game development, the six paradigms can be classified into four stages: initiation, production, testing, and release. The steps are categorized, yet they do not adhere to a linear sequence. The procedure consists of several iterations across different phases and combinations of steps, informed by various aspects of the study conducted. Gamified applications created through frameworks emphasizing testing and release stages, such as the Game Development Life Cycle (Sucipto et al., 2023) and Stage Narrative Development (Kerlow et al., 2020), have resulted in successful launches. Applications such as "Cikeas - Cileungsi Overflow" and "Earth Girl Volcano" serve as pertinent examples. In contrast, games developed through alternative paradigms have demonstrated lesser success. This illustrates that the final phases of game development are equally important as the initial stages.

Figure 4.2

Board and Video game of “Costa Resiliente” game



Note. Figures left to right: (1) Board Game - Source : <https://diario.uach.cl/> and (2) Video Game - Source : <https://pru-lab.cl/>

The transition of the board game into a digital format via a mobile application (Figure 4.2) enhanced the participants' gaming experiences by enhancing their perception of achievement, challenge, playability, immersion, social experience, and support (Olivares-Rodríguez et al., 2022). These findings are corroborated by the implementation of automated rules and mechanics using algorithms, which decreases the amount of cognitive effort required in the game and enables participants to concentrate on their decision-making and the game's designed topics. The findings demonstrated that the implementation of gamification can effectively promote the development of resilience thinking, thereby highlighting its potential as a valuable technique. Research conducted by Olivares-Rodríguez et al. (2022) has demonstrated

that active learning, particularly when implemented through game-based methods, leads to greater levels of learning retention compared to traditional learning sessions. Player feedback indicates that the incorporation of individuals and vehicles, including cars and buses, is essential for accurately simulating realistic flood scenarios. Expanding the range of building types, including residential and commercial structures, illustrates the varied environments impacted by flooding. Incorporating natural settings, including waterfalls, rivers, and mountains, provides a comprehensive perspective on the interaction between floods and the landscape. Prolonging gameplay duration facilitates deeper engagement, and the addition of extra levels presents progressive challenges that maintain interest and promote learning. Incorporating sounds such as rain, flowing water, or emergency sirens enhances the sensory experience, thereby increasing the simulation's impact and memorability for young learners.

4.2 Contribution of gamified application to the awareness raising pertaining to flood disasters among children and youth

Gamified applications for disaster management effectively educate students on strategies to protect themselves from the severe consequences of natural disasters. [Sabo \(2012\)](#) posits that these games improve students' capacity for long-term strategic thinking, as opposed to concentrating solely on immediate results. The implementation of disaster preparedness involves an individual utilizing a prototype gamification application to educate participants on disaster preparation. The conventional method requires the participation of 300 personnel for information dissemination ([Arinta et al., 2020](#)).

Research indicates that gamified applications are ineffective as standalone activities in disaster education ([Gampell et al., 2021](#)). They necessitate integration into activities based on social groups ([Gampell et al., 2020](#)). It is essential for at least one individual to offer explanations and education to the participant concerning disaster preparation through the prototype gamification application ([Arinta et al., 2020](#)). Alternatively, the participant should engage in a traditional course accompanied by a discussion of the concepts learned ([Taillandier & Adam, 2018](#)). Frequent evolution of game concepts is essential for maintaining user engagement. Neglecting this may lead to a decline in

user interest and engagement with the game (Molan & Weber, 2021). Although these games are often labeled as serious games or gamified applications, many do not fulfill the criteria for classification as a game, as they lack clearly defined objectives for participants and challenges to surmount. Nonetheless, these games continue to offer enjoyment and generate interest (Skinner, 2020).

The 5-step learning package employed for initial testing, based on Kolb's Experiential Learning Cycle, positively impacted the participants, with approximately 90% providing correct responses on the post-test questionnaire. Over 85% of respondents indicated an increased familiarity with flood preparedness and mitigation concepts following their engagement with the game "Disaster Defenders." In the second round of testing, students exhibited an average overall satisfaction rating of 90.1 regarding the gaming experience. Additionally, 86% of the students demonstrated a comprehensive understanding of the gamified application. The game remains in the development phase, having completed two testing iterations. This paper examines the outcomes and future trajectory of the game process. The findings indicate that the developed game is effective in enhancing children's engagement with disaster prevention and increasing their motivation to partake in related activities.

4.3 Limitations and Recommendations for future development

The study has several limitations, notably that land use, urbanization, heavy rainfall, and vegetation cover all influence flooding. Additionally, floods may also result from landslides and the opening of reservoir dams, which are not addressed in the research. Players have the option to select from seven distinct types of construction possibilities. Consequently, players possess fewer construction options compared to a real-world scenario. The current gamified application has limited multiplayer functionality, supporting a maximum of three players simultaneously.

In the future, gamified applications may incorporate chatbots and intelligent agents to improve the gaming experience and facilitate certain communication aspects (Sampson et al., 2023). Additionally, few studies have combined AR, VR, Mixed Reality (XR), and Artificial Intelligence (AI) within gamified applications for disaster education (Kankanamge et al., 2021). These technologies have been effectively employed in the fields of tourism and culture (Bugeja & Grech, 2020). Thus, integrating these technologies can enhance the extensive application of gamification

in disaster education. Scholars can analyze the gameplay of gamified applications to assess their complexity and suitability for specific target groups in disaster education.

4.4 Recommendations for practitioners

This gamified application serves as a vital resource for schools, disaster management organizations, NGOs, policymakers, and game developers in improving flood disaster education. Educational schools and teachers may include the program into geography, environmental science, or disaster preparation curriculum, using it as an interactive learning resource to enhance student engagement and information retention. Disaster management organizations and municipal authorities may use it for public awareness initiatives, educational outreach programs, and community disaster preparation training, ensuring that children and youth comprehend flood hazards and mitigation techniques. Non-governmental organizations engaged in disaster resilience, child safety, and climate adaptation, like UNICEF and the Red Cross, may integrate the game into community-based educational initiatives, using its interactive methodology to improve awareness in flood-prone areas. Urban planners and environmental groups may use the program to include communities in flood risk assessment and sustainable land-use strategy development.

Successful deployment necessitates cooperation among schools, disaster management organizations, and technological partners to enhance the application's reach and efficacy. Training workshops for educators and community leaders may facilitate appropriate use, while public awareness campaigns and disaster drills can incorporate the game into practical preparation programs. Policymakers may facilitate the official integration of gamified disaster education into school curriculum, so assuring sustained involvement. Moreover, future advancements may include adapted variation addressing region-specific flood hazards, multilingual capabilities, and mobile/web accessibility. Integrating this tool into educational and disaster preparation programs enables practitioners to cultivate a culture of resilience among children and their communities, helping them to make educated choices during crisis scenarios.

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APPENDICES

Appendix – 01 :

Questions and responses of the pre and post-test questionnaire for Testing 02

Question	Response
Q1 - If you are building a house, which area do you prefer the most?	R1 - Close to a river
	R2 - Close to a marshy land
	R3 - Close to high elevated area
	R4 - Close to a town area
	R5 – Other
Q2 - As you think, how does the flood occur?	R1 - Overflowing rivers due to high rainfall
	R2 - Rapid urbanization
	R3 - Land-filling (Constructions on Marshes)
	R4 – Deforestation
	R5 - Other
Q3 - If a flood occurs, what are the areas do you think will inundate immediately?	R1 - Marshy Lands
	R2 - Lands close to river
	R3 - High elevated areas
	R4 - Lands close to roads
	R5 - Other
Q4 - If a flood occurs where do you usually go to escape?	R1 – School
	R2 - Hospital
	R3 - High elevated areas
	R4 – House
	R5 - Other
Q5 - As you think, how to reduce flood damage in town?	R1 - Increasing the forest cover
	R2 - Avoiding high dense built-up
	R3 - Avoid land-filling (Avoid filling marshy lands)
	R4 - Avoid constructions in the river reservation areas
	R5 - Other