Floodcraft: Game-based Interactive Learning Environment using Minecraft for Flood Mitigation and Preparedness for K-12 Education

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Abstract

Flooding poses a significant threat to communities worldwide, yet educational methods to teach flood mitigation strategies are often lacking in engagement and practical application. This study introduces Floodcraft, an open-source educational game developed using the Minecraft platform to teach K-12 students about flood preparedness and mitigation methods interactively. The game encompasses four key tasks, each representing a distinct flood mitigation strategy: building floodwalls, sandbagging, wet floodproofing, and elevating structures. Players must complete these challenges successfully, demonstrating the proper application of each approach. The game and its tasks were implemented using a combination of Minecraft modding and commands. Floodcraft aims to engage younger generations in learning about flood risks and mitigation strategies through an enjoyable, hands-on experience. By leveraging Minecraft's platform, the game promotes creativity and enjoyment in the learning process. Floodcraft contributes to the formation of resilient, environmentally conscious communities by encouraging children to participate in flood protection strategies from an early age. This innovative educational tool enables students to acquire practical knowledge about flood damage mitigation while fostering problem-solving skills and a sense of responsibility.

Keywords: K-12 education, flood management, flood risk, flood mitigation, gamification, serious gaming.

1. Introduction

Flooding is one of the most frequent and devastating natural disasters worldwide. According to the UN, floods affect over 2.8 billion people globally each year, resulting in widespread destruction and loss of human life (UNDRR, 2020). The impacts of floods are far-reaching, causing significant economic damages as homes, infrastructure, and agriculture are damaged or destroyed (Ashizawa et al., 2022; Carrera et al., 2014; Alabbad et al., 2023). Flooding also causes health challenges due to water contamination, spreads water-borne diseases, and displaces millions from their homes (Kamalanandhini et al., 2019). Floods are threatening human lives with over 100,000 flood-related deaths occurring between 2000-2009 alone (Doocy et al., 2013; Li and Demir, 2022). Implementing effective flood mitigation strategies is therefore critical for building resilience and adapting to increased flood risk in a changing climate (Yildirim et al., 2022; Cikmaz et al., 2023). Key flood mitigation approaches include building flood barriers, elevating structures, and flood-proofing buildings (Demiray et al., 2023). Educating and preparing communities to use protective engineering measures is essential to reduce the impact of floods now and in the future (Sermet and Demir, 2022).

Teaching young people about flood planning and protection is essential for building strong communities (Carson et al., 2018). Due to the more frequent and severe floods resulting from climate change, it is crucial to ensure that children and teenagers have the knowledge to understand and actively contribute to protective measures (Rieckmann, 2017; UNDRR, 2015). By helping them learn about flood risks and how to mitigate them early on, the younger generation is empowered to actively participate in making their communities safer (Yildirim et al., 2023). This type of education also helps develop a sense of responsibility and environmental awareness in individuals from a young age, encouraging them to make informed decisions and adopt sustainable practices (Mudiyanselage et al., 2024). Investing in the education of young people on flood protection not only protects communities but also helps develop a generation capable of making meaningful contributions to a safer and more sustainable future (Marouli, 2021).

Minecraft is one of the most popular video games globally, with over 140 million monthly active users as of 2021 (Clement, 2022). Its immense popularity among children and teenagers makes it an ideal platform for creating engaging educational content (Opmeer et al., 2018). Recent research has demonstrated the value of using Minecraft to teach complex topics in fields like engineering, science, and environmental studies (Callaghan, 2016). Research shows that using games like Minecraft for educational purposes improves the learning experience of the students (Bourdeau et al., 2021).

For example, a 2017 study conducted an experiment with 118 elementary school students and found that there are many benefits of using Minecraft games at schools such as creating a positive learning environment, improving the problem-solving skills of the students, and encouraging students to be creative (Karsenti et al., 2018). Serious games that simulate real-world environments and systems are powerful tools for motivating students towards the goal of learning new concepts and being creative. Using a familiar platform like Minecraft increases students' existing interests and makes the learning process more enjoyable. An online survey showed that 90% of the participants think gamification makes the learning process more exciting (Baek et al., 2020).

The paper presents the development of an educational Minecraft game focused on teaching flood mitigation strategies to children with support from intelligent conversational assistance through Large Language Models (LLMs). Key mitigation methods like floodwalls, sandbagging, wet floodproofing, and elevation are implemented in the gameplay. The game provides an engaging, hands-on learning experience to improve students' understanding of flood protection techniques. The key contribution of this study is the design and development of an innovative serious game that leverages Minecraft's popularity to motivate younger generations to learn critical flood mitigation strategies and inform the public about the decision-making processes. The gameplay and interactive tasks are developed to teach essential engineering concepts and empower students and the public to contribute solutions for building community resilience.

The paper is organized as follows. Section 1.1. reviews the literature on the use of Minecraft and serious gaming for educational purposes, specifically focusing on STEM education, disaster management, and hydrological education. In Section 2, we describe the development process of Floodcraft, including game concept and design, mod development, city design, gameplay mechanics, and technical requirements. Section 3 presents the outcomes of implementing Floodcraft, focusing on its educational impact, gameplay experience, and the integration of ChatGPT for enhanced learning. In Section 4, recommendations for future work are provided, suggesting avenues for expanding and enhancing Floodcraft's educational capabilities. Finally, Section 5 summarizes the key findings and implications of the study, emphasizing the potential of Minecraft as a platform for delivering engaging and effective educational content on flood mitigation strategies.

1.1. Related Work

In the changing world of online learning, Minecraft Education Edition (MEE) has become an important tool (de Sena, 2023). It uses the popular world of gaming to make learning fun and interesting. This literature review examines how MEE is used for education and how the usage of Minecraft in the education field can be improved. Science Hunters is an outreach project that utilizes serious gaming through MEE games to teach STEM concepts. It began in 2014 at Lancaster University in the UK and has since moved its base of operations to the University of the West of England (UWE) Bristol (UWE Bristol, 2014). Those involved in this project have made a collection of MEE games that they have used to conduct studies on upwards of 20,000 children across the UK to determine the efficacy of learning STEM concepts via MEE games and have also been hosted at various science fairs and STEM events across the country.

Another study, Participatory Minecraft mapping: Fostering students' participation in disaster awareness, explores the educational use of Minecraft, focusing on its application in teaching about disaster risk reduction (DRR) through a method co-designed by educators, students, and emergency professionals (Gampell et al., 2024). Moving beyond the initial skepticism of video games in education, this research positions Minecraft as a valuable tool for bridging the gap between entertainment and learning. The game's wide appeal and its potential to support constructivist learning principles are highlighted, demonstrating how Minecraft can encourage active participation and problem-solving among students. This approach reflects a broader trend towards integrating interactive technologies in education,

offering insights into how popular video games can be adapted for educational purposes to engage students in complex topics like disaster preparedness effectively (Menendez-Ferreira et al., 2024; Sermet and Demir, 2020).

The current market for educational games within Minecraft Education Edition (MEE) offers a diverse array of environments focused on environmental education, including titles such as Rivercraft, Climate Warriors, Climate Futures series, and Frozen Planet series (Holik et al., 2024). These games tackle critical topics like climate change, ecological conservation, and sustainable practices through interactive, game-based learning (Kersánszki et al., 2023). Despite their innovative approach to education, several limitations have been identified, indicating room for enhancement and further development in this niche (Tan and Nurul-Asna, 2023).

Across the playable environmental MEE games found, there was some diversity in the overall game designs. The first kind of game is called *Experience Build*. These games are done in a linear based style, where the player is given various small tasks to complete before moving on to the next area or task. These games are typically NPC driven and players can typically find their way from one area to the next via teleportation means or signage easily. The second game type is called *Expression Build*. These games are meant to be more of a platform for players to create something that serves some sort of environmental purpose and often seem to be made with the expectation that someone outside of the game (such as a teacher in a classroom) is providing instructions.

These games often have files that can be downloaded in addition to the game that give insight to its purpose, and it is up to the instructor to inform the player of said purpose and the importance of their task. There are also a select few games that are referred to as a Museum Build and are simply worlds constructed to act as a visual aid to teaching environmental concepts. In these games, the player does not actually have to do any tasks at all except travel through the world and follow along, either reading dialogue from NPCs or reading signage throughout the world that inform them of the target concepts.

There are some trends when it comes to specific goals players are expected to achieve throughout the games (Bar-El and Ringland, 2020). One common goal of the games is to have the player learn about climate change and the environment they are in, and the hazards associated with it, and then have user implement mitigation strategies to prevent those hazards and minimize effects on climate change. These are things like building flood walls, practicing recycling, planting trees, building dams, placing infrastructure in smart locations relative to hazards, and implementing disaster evacuation procedures. Another large theme seen across the environmental games is the focus on habitat education and protection.

Many of the games have players conduct an ecological survey of local wildlife. This is done by having the player fill out a “workbook” with pictures they take of various animals and plants in an environment. The player then takes notes about the habitat, morphology, or biology of the various wildlife. This workbook is then evaluated for completion either by an NPC or out-of-game instructor. The camera and portfolio items used in this process are unique to MEE. There are also games that have players build a suitable habitat for a species or lead animals to safety within their environments. In the Frozen Planet games, players are also able to play as the animals themselves and do things like hunt for food or build nests for their young. There is another area of focus when it comes to environmental MEE games,

which is in the form of coding. In these games, environmental mitigation/habitat restoration goals are achieved via in-game coding algorithms made by the player using the built-in Code Builder interface.

One of the primary shortcomings in existing MEE games is the lack of direct feedback and achievement recognition for players. Games like Rivercraft introduce players to environmental concepts and tasks such as flooding, ecological surveys, and climate change strategies but often fall short in providing explicit feedback on the effectiveness of player actions. For instance, after completing tasks, players may not receive clear indicators of success or areas for improvement, which can lead to a lack of understanding regarding the impact of their actions within the game. Moreover, the absence of a scoring system or achievement recognition can diminish the motivational aspect of gameplay, making it challenging to gauge progress or compare performance over time (Weisi and Hajizadeh, 2025).

There seems to be a gap in the serious gaming industry regarding games that effectively teach flood mitigation strategies to children. While existing games like Rivercraft touch on some flood concepts, they lack clear instructions, feedback mechanisms, and reward systems to properly reinforce the learning. A more comprehensive flood mitigation game like Floodcraft fills this gap by incorporating additional mitigation activities like sandbagging, elevating the structure, wet floodproofing, and building floodwalls. Clear step-by-step guidance from NPCs along with the scoring system help players understand expectations and performance. Overall, Floodcraft provides a more engaging, hands-on learning experience compared to current offerings.

2. Methods

We developed a serious gaming framework aimed at educating children on flood mitigation strategies. The game utilizes the Minecraft platform with specific modifications to meet the project's objectives. The description of the proposed work is organized into five subsections: game concept and design, mod development, city design, gameplay mechanics, and technical requirements. Figure 1 depicts the overview of the system architecture and components.

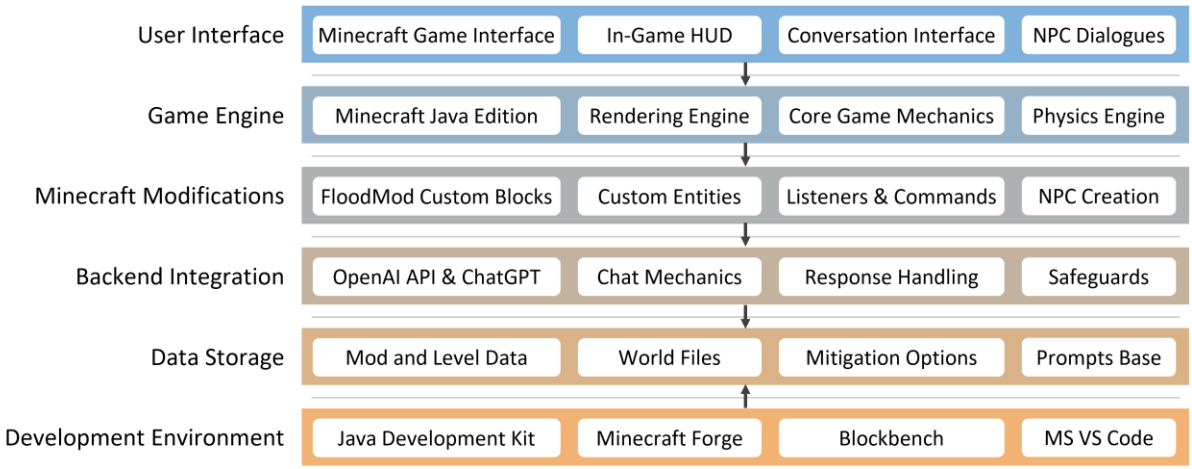

Figure 1: System architecture and components of the FloodCraft.

2.1. Game Concept and Design

Floodcraft is an educational game built on the Minecraft platform, chosen for its popularity among the target audience (Mavoa et al., 2018). The familiarity and engaging nature of Minecraft facilitate an improved learning experience for users (Andersen and Rusted, 2022). Among the various editions of Minecraft, Minecraft Java, Minecraft Bedrock, and Minecraft Education were considered for this project. Ultimately, Minecraft Java was selected based on several criteria including compatibility with Windows, macOS, and Linux operating systems; the ability to extensively modify the original code; and support for using non-player characters (NPCs) in gameplay. Other editions, such as Minecraft for Xbox, PlayStation, or China Edition, were excluded due to their limited platforms and availability (Minecraft Help Center, 2024).

Minecraft Java Edition was deemed the most suitable for this project as it meets all the specified criteria. Minecraft Bedrock is not compatible with macOS, and Minecraft Education Edition does not support Linux, making them less viable options (Minecraft Help Center, 2024). Additionally, the limited resources and modifications available for Minecraft Education Edition further justified the choice of Minecraft Java Edition. Although Minecraft Java does not natively include NPCs, various mods available online enable this functionality. The CustomNPCs mod was selected for this project due to its compatibility with the Minecraft version used. This mod allowed the integration of NPCs to guide players through the educational tasks, providing instructions and feedback.

In Minecraft Java Edition 1.16.5, four game modes are available: adventure, creative, survival, and spectator. Each mode offers different rules and player capabilities. Adventure mode restricts block placement or destruction, making it unsuitable for this project. Creative mode grants unlimited power, allowing players to place or destroy blocks freely, which could disrupt the intended gameplay mechanics. Spectator mode enables players to fly and observe but not interact with the environment, rendering it inappropriate for the educational objectives (Minecraft Wiki, 2024). Survival mode was chosen as it allows block placement and destruction with certain restrictions, aligning with the project requirements. Specific tools are needed to destroy certain blocks, and players can only use blocks and items specified by the developer, making the gameplay challenging yet controlled. Additionally, mob generation was disabled to maintain focus on the educational tasks.

Floodcraft's gameplay is structured around four key flood mitigation strategies: floodwall construction, sandbagging, wet floodproofing, and elevating structures. Each task represents a distinct strategy, providing practical, hands-on learning experiences. Floodwalls are concrete barriers designed to keep water out up to a certain height, though they can be costly and cause drainage issues (FEMA, 2007). Elevating buildings on columns or fill material is effective but often prohibitively expensive (FEMA, 2007). Sandbagging involves using sand-filled barriers to divert floodwaters, which is inexpensive and easy to install but labor-intensive and only temporarily effective (FEMA, 2007). Wet floodproofing allows water to enter without causing structural damage, requiring significant cleanup post-flood (FEMA, 2007). Each strategy has its benefits and limitations related to costs, permanence, aesthetic impacts, and floodwater redirection, necessitating careful analysis when selecting appropriate methods (Alabbad and Demir, 2022; Tanir et al., 2024).

At the start of the game, players are spawned in the town hall, where they receive instructions from an NPC. Initiating the game teleports them to their first mission, which involves placing a floodwall around a river. Players can control the flooding setup through in-game buttons to test and adjust their solutions. Successful completion of this task advances them to the next mission, which involves protecting a building using sandbags. The same procedure is followed for subsequent tasks, including wet floodproofing and elevating structures.

In the wet floodproofing task, players use andesite blocks to cover the building's base while leaving certain parts open. Points are awarded based on the extent of void spaces created and the safety of the building. Visual examples and NPC guidance are available to assist players. The final task involves elevating a structure using designated blocks, with instructions provided through images and NPCs. Upon successful completion of all tasks, players are teleported to a sign indicating their victory. This structured approach ensures that players gain a comprehensive understanding of various flood mitigation strategies through interactive and engaging gameplay.

2.2. Mod Development

Minecraft modifications, commonly known as "mods," are used to enhance and expand the game's functionality by adding new blocks, items, and entities or altering the features of existing ones (Dodge, 2024). Mods can significantly enrich the gaming experience by introducing diverse elements and demonstrating the developer's creativity. To implement mods in Minecraft Java Edition, the Java programming language is used, and an appropriate mod API is required to act as a layer between the custom code and the Minecraft game itself (Crémer, 2024).

For the Floodcraft project, Minecraft Forge was selected as the mod API due to its extensive compatibility with various external mods and its widespread use in the modding community. This choice facilitates future improvements and ensures compatibility with other mods, such as CustomNPCs, which was utilized to integrate non-player characters (NPCs) into the gameplay. The CustomNPCs mod was essential for creating interactive dialogues and guiding players through educational tasks.

Three new blocks were added to the original Minecraft inventory: sandbag_block, floodwall_block, and floodproof_block. These blocks were specifically designed for the Floodcraft tasks. The design process involved using Blockbench, a 3D model editor that allows the creation of Minecraft entities, blocks, and items with or without animations. Blockbench generates JSON files and texture files in png format, which are then organized into subfolders under the assets folder in the project directory. A JSON file was created to specify the names of the newly added blocks and items as they appear in the game.

The properties of these blocks, such as materials, resistance, harvest tools, and harvest levels, were defined and registered through code. The floodproof block was designed with custom physics to enhance the realism of the gameplay. Unlike standard Minecraft blocks affected by gravity, such as sand and gravel, the floodproof block's behavior depends on its support from neighboring blocks. This was achieved by leveraging event listeners in Minecraft to create unique physics for the floodproof block.

To facilitate interaction with ChatGPT within the game, an event listener was created to monitor chat events. Players can access the chat function by pressing "T" on the keyboard. Commands that start with "/" are not sent to ChatGPT, while other prompts are processed. The event listener captures these prompts and sends them to a method that communicates with ChatGPT via the OpenAI API (Simpson, 2022). The responses from ChatGPT are then displayed on the player's screen using another event listener. To enable this functionality, dependencies for Forge and JSONObject were added to the build.gradle file.

To use any mod in Minecraft gameplay, the jar files must be placed inside the mods folder within the Minecraft directory. This simple step allows for the seamless integration of custom modifications into the game. The integration of NPCs was achieved using the CustomNPCs mod, which enabled the creation of interactive dialogues. NPCs were used to inform players about the tasks and provide guidance throughout the game. This interaction adds a layer of depth to the educational experience, making it more engaging and informative for the players.

2.3. City Design

The design of the city in Floodcraft is fundamentally aimed at educating children about flood mitigation strategies. The city serves as an interactive environment where players can engage in various tasks that simulate real-world flood scenarios. The primary objective was to create a realistic, educational setting that would enhance the learning experience. In constructing the city, external structures were utilized, which were downloaded from the internet as NBT (Named Binary Tag) files. These NBT files contain detailed information about Minecraft structures and can be imported into the game using structure blocks. This approach allowed for the incorporation of diverse and complex structures into the game world, enriching the overall environment.

The city is designed to resemble a small town with a river running through it, providing a realistic context for flood simulation. Players begin their journey in the town hall, which serves as the central hub for receiving instructions and starting tasks. Upon initiating the game, players are teleported to their first mission, which involves addressing a potential river overflow. This setup is designed to immerse players in a scenario where they must apply flood mitigation strategies to protect the town. The use of structure blocks and external NBT files facilitated the creation of a dynamic and engaging city environment. This design choice not only added variety to the game but also ensured that the city layout was both educational and visually appealing. The river, town hall, and other structures were strategically placed to create a cohesive and realistic setting for players to explore and learn about flood risks and mitigation techniques.

2.4. Gameplay Mechanics

The gameplay mechanics of Floodcraft leverage Minecraft's command system to perform various operations essential for the educational objectives of the game. Minecraft commands are powerful tools that can alter gameplay mechanics and are typically only available when cheats are enabled. However, for the purposes of this project, player cheats are disabled by modifying the level.dat file in the Minecraft directory. This ensures that players cannot alter the game mechanics, maintaining the intended educational experience. Instead, player actions

are controlled by hidden command blocks placed underground, which execute a variety of commands to facilitate gameplay. Table 1 summarizes the most frequently used command types in Floodcraft.

Table 1: Most frequently used command types in Floodcraft.

Command Type	**Description**
execute if	*Executes another command if a specified condition is satisfied.*
clone	*Copies a specified area of blocks. Used primarily to count specific blocks in an area.*
scoreboard	*Manages score operations, including printing scores, storing variables, performing arithmetic operations, and checking score conditions.*
title	*Displays a message on the player's screen.*
tp	*Teleports the player to specified coordinates. Used to move players between tasks.*
fill	*Fills an area defined by two sets of coordinates with a specified block type.*
setblock	*Sets a block at specified coordinates to a given block type.*
gamemode	*Changes the game mode. Available modes in Minecraft Java Edition 1.16.5 include adventure, survival, creative, and spectator.*
gamerule	*Controls various game features such as daylight cycle, mob spawning, player respawning, and weather cycle.*
give	*Adds a specified block to the player's inventory.*
setworldspawn	*Sets the starting coordinates where players will be spawned initially.*
time	*Sets the game time. In Floodcraft, the time is always set to day, and the daylight cycle is disabled using the gamerule command.*

Command blocks are the core mechanism used to implement these commands. There are three types of command blocks: repeat, chain, and impulse. Repeat blocks execute commands every Minecraft tick (0.05 seconds), chain blocks execute each time they are activated, and impulse blocks execute a command once when activated. Additionally, command blocks can be configured with different activation types—"always active" or "needs redstone"—and condition types—"conditional" or "unconditional." These configurations allow for the creation of complex command sequences where the output of one command affects the activation of subsequent command blocks. This mechanism is used to detect player actions, such as pressing a button, counting blocks in a specific area, or identifying block types at certain positions.

2.5. Technical Requirements

To effectively utilize the Floodcraft system, certain technical prerequisites and installation steps must be followed. The primary requirements include Java Development Kit (JDK) 8,

Minecraft Java Edition, and Minecraft Forge 1.16.5. Java 8 is essential for running Minecraft Java Edition and the associated mods, providing the necessary runtime environment. Minecraft Java Edition serves as the primary platform for Floodcraft due to its compatibility and extensive modifiability. Minecraft Forge 1.16.5 is required as a modding platform to integrate external modifications such as CustomNPCs and Floodmod.

The installation of the CustomNPCs mod begins with downloading the CustomNPCs jar file from a reliable source, such as CurseForge. Once downloaded, users need to locate the Minecraft directory on their system. Within the Minecraft directory, there is a 'mods' folder where the CustomNPCs jar file should be placed. This step is crucial for enabling non-player characters (NPCs) within the game, which play a significant role in guiding players through the educational tasks. Similarly, the installation of the Floodmod requires downloading the jar file from the project's GitHub repository.

After ensuring that the Minecraft directory and the 'mods' folder are accessible, the Floodmod jar file should be moved into the 'mods' folder. This mod introduces new blocks and functionalities critical to the Floodcraft gameplay, including floodwalls, sandbags, and wet floodproofing techniques. To set up the game environment, the world folder must be downloaded from the project's GitHub repository. The downloaded world folder should be extracted and placed into the 'saves' directory. Upon launching Minecraft Java Edition, the Flood World will appear as an available world option. Selecting this world initiates the Floodcraft gameplay, allowing users to engage with the educational content and interactive tasks.

3. Results

Floodcraft creates an immersive, game-based learning environment to educate children on key flood mitigation techniques and demonstrate how experts make decisions about flood protection methods. The gameplay consists of four interactive challenges, each simulating the real-world application of a specific floodproofing strategy – building floodwalls, sandbagging vulnerable structures, wet floodproofing, and elevating buildings above expected flood levels.

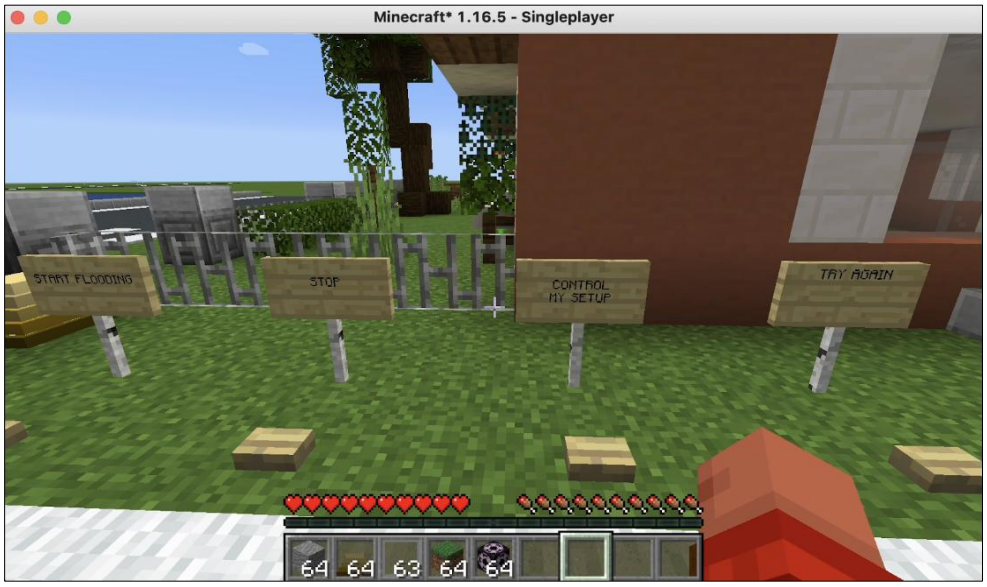

Figure 2: Game control mechanism and interaction.

Students can tackle these simulated mitigation tasks through a trial-and-error approach enabled by in-game control buttons as shown in Figure 2 that trigger flooding events. After attempting their own flood barrier setups, players can initiate rising water levels to test the effectiveness of their solutions, then modify their designs accordingly. This hands-on experimentation system provides an engaging way for children to actively learn the proper utilization of various flood mitigation strategies.

By letting students freely explore floodproofing techniques and see the consequences of their choices, Floodcraft's gameplay mechanics promote a deep understanding of how to correctly implement the different protection methods. The interactive nature of the mitigation activities paired with the instant feedback empowers self-directed learning about selecting suitable solutions tailored to diverse real-world flooding scenarios.

The Floodcraft game provides players with clear instructions and visual guidance throughout each task to effectively clarify expectations and learning objectives. For example, when players are tasked with implementing flood mitigation strategies, the non-player character (NPC) that is shown in Figure 3 guide provides explicit step-by-step directions for building a flood wall using concrete blocks. The instructions provided by one of the in-game NPCs can be seen in Figure 4. Additionally, informational signs with accompanying diagrams as in Figure 5 are positioned to demonstrate proper material placements and overall technique. These detailed images serve as useful references that help visualize key mitigation concepts.

Figure 3: Non-Playable characters in the game.

By coupling clear verbal instructions with visual aids, the game promotes active learning. The result is an engaging, hands-on activity made understandable even for those with limited prior knowledge. This instructional design reflects best practices for educating players on practical emergency preparedness skills in an enjoyable gaming environment. In summary, Floodcraft integrates explicit NPC guidance and visual references to provide players of all ages with a clear understanding of flood mitigation goals and procedures. This combination of textual and visual information ensures an educationally impactful gameplay experience.

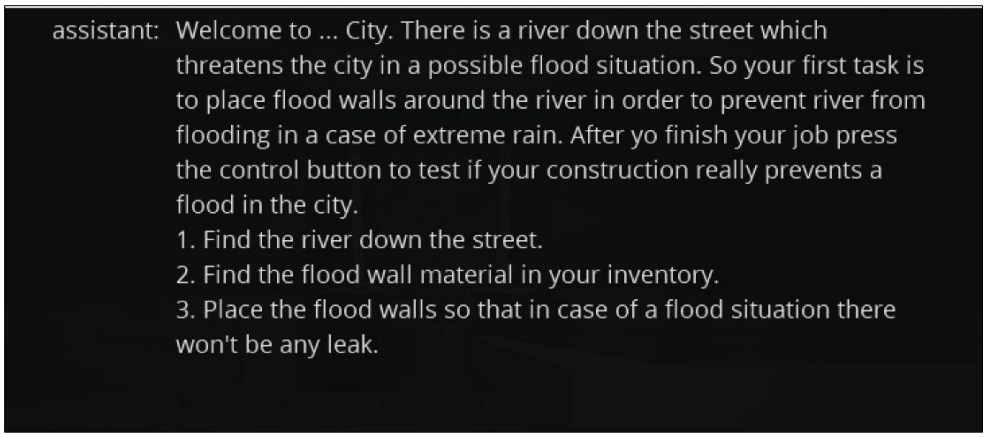

Figure 4: Instructions for gameplay via NPCs.

Figure 5: Visual aids and educational materials for learning

The integration of ChatGPT into Floodcraft's in-game chat provides players with an intelligent conversational agent to enhance the learning experience (Figure 6). Players can engage in natural language dialogs with the AI assistant to get helpful explanations, tips, and answers to their questions as they progress through the game's flood mitigation tasks (Figure 7). Having an AI companion in the chat streamlines the learning process and has the potential to keep players motivated. Rather than getting stuck or frustrated, players can simply describe their issues to ChatGPT, which will provide customized guidance. The AI can clarify concepts, give examples, offer troubleshooting suggestions, and generally assist players in applying the flood mitigation techniques properly. Players are free to inquire about anything related to the challenges or flood protection methods.

ChatGPT makes the game more fun and engaging by enabling free-flowing conversations that feel tailored to each player's needs. The AI's responses help players stay focused on the learning objectives while exploring ideas. Allowing players to tap into this powerful knowledge resource directly through the in-game chat is an innovative way to captivate student interest and promote self-directed active learning. By integrating conversational AI,

Floodcraft transcends a static gaming experience to become an adaptive, interactive environment for developing flood resilience skills.

Figure 6: Intelligent assistance via natural language conversation

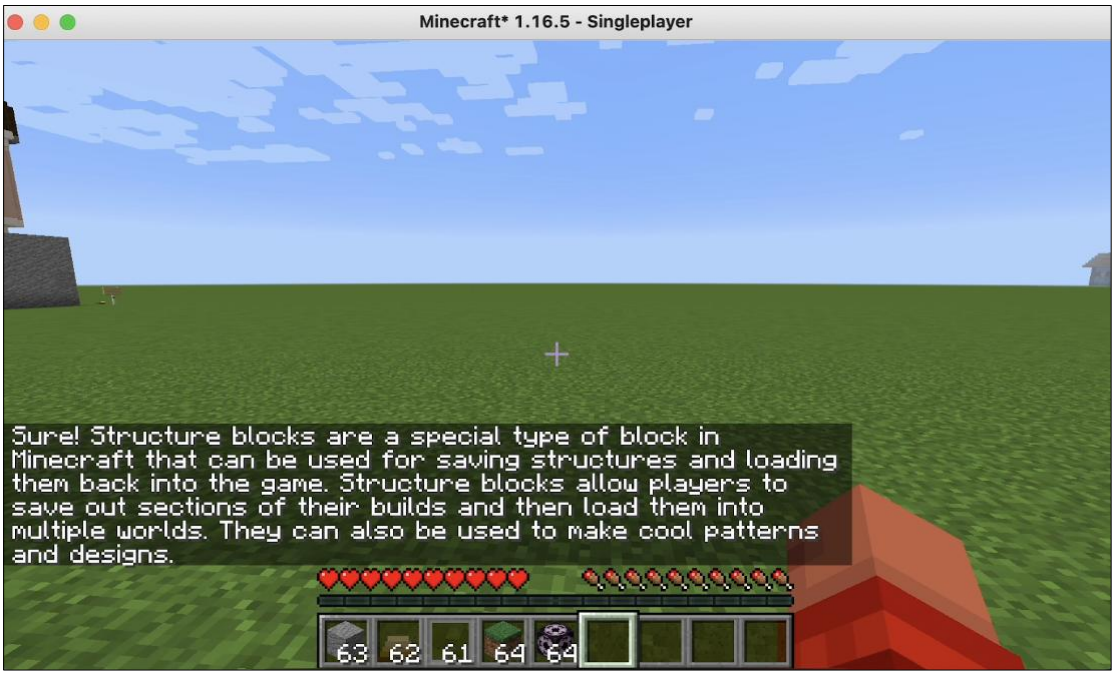

Figure 7: AI-powered assistance through safeguards

New blocks with customized models, textures, and behaviors are added to Floodcraft to simulate real-world materials used in flood mitigation strategies (Figure 8). By making the new blocks visually and functionally mimic their real-world counterparts, players can learn proper application techniques more intuitively while enjoying an authentic floodproofing

experience within Minecraft. The customized models, textures, and physics help reinforce the learning process.

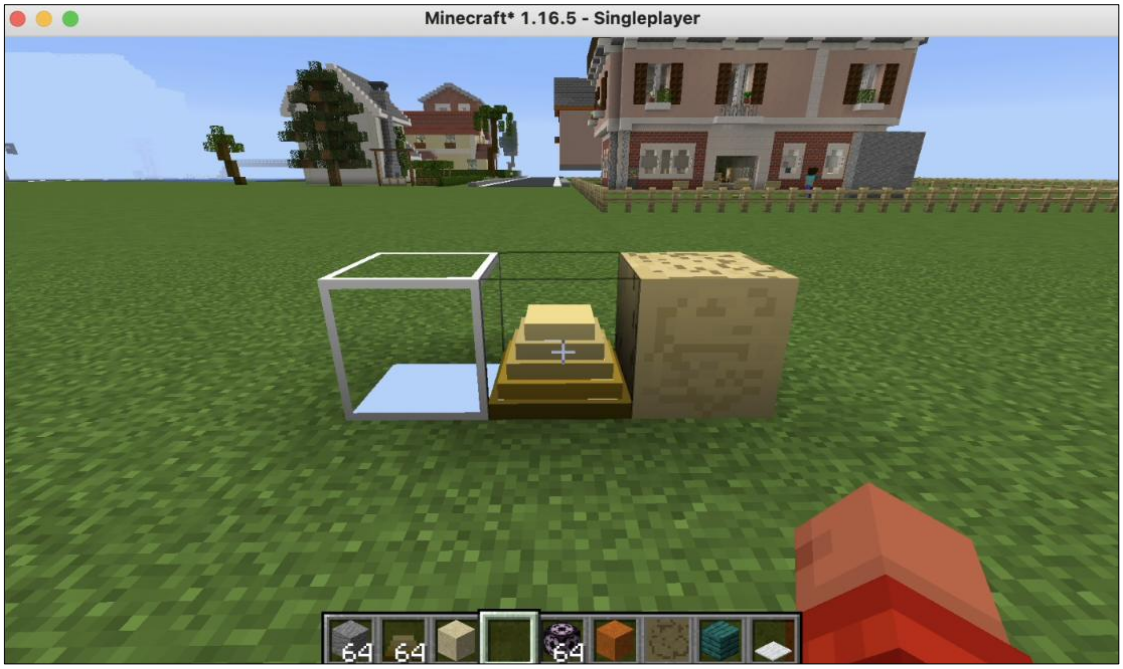

Figure 8: Custom game blocks (e.g., sandbag, floodwall)

4. Discussions

The Floodcraft interactive learning system has presented to a large group audience at the 2024 International Environmental Modelling and Software (IEMS) Conference which provided valuable qualitative insights from a diverse group of educators, domain experts, and professionals in the field of disaster management. Feedback gathered during and after the presentation highlighted several strengths and weaknesses of the system, as well as potential areas for future development and improvement.

Participants expressed strong interest in Floodcraft's potential as an educational tool. Attendees appreciated the innovative use of Minecraft to teach flood mitigation strategies, praising its ability to engage younger audiences. Many highlighted the importance of hands-on, interactive learning experiences in enhancing students' understanding of complex topics like flood protection. The integration of gamified elements, such as interactive tasks and NPC-guided instructions, was noted as a major strength. Participants agreed that these features make learning more enjoyable and could significantly increase student motivation and participation.

However, some participants raised concerns about the complexity of the game mechanics and the steep learning curve for younger or less tech-savvy users. Suggestions were made to simplify certain aspects of the game to ensure accessibility for all age groups. Questions were raised about the accuracy of the information provided by the in-game ChatGPT assistant. Ensuring that the AI responses are reliable and up to date was deemed crucial for maintaining educational integrity (Sajja et al., 2023a; 2023b). The potential for further customization of the game environment was a recurring theme.

Participants suggested allowing users to create and simulate their own cities, which would make the learning experience more relevant and engaging. This feature could also encourage players to think critically about flood mitigation strategies within the context of their own communities. Some technical challenges were identified, particularly related to the integration of new blocks and the use of external mods. The dependence on specific versions of Minecraft and Forge could limit the system's accessibility and ease of use. Addressing these technical dependencies would be important for broadening the system's reach.

Floodcraft successfully leverages the popularity of Minecraft to create an engaging educational tool. The use of gamification and interactive tasks captures students' interest and encourages active participation. By simulating real-world flood mitigation strategies, Floodcraft provides practical, hands-on learning experiences that enhance students' understanding of flood protection methods. Additionally, the integration of ChatGPT offers real-time, personalized assistance (Sajja et al., 2023c), making the learning process more dynamic and responsive to individual needs.

However, the game's complexity may pose a challenge for younger or less experienced users. Simplifying the game mechanics and providing more intuitive controls could improve usability. Ensuring the accuracy and relevance of the AI-generated responses is critical. Mechanisms to verify and update the information provided by ChatGPT are necessary to maintain educational credibility. While the current version of Floodcraft offers a structured learning environment, there is a need for greater customization options. Allowing players to create and simulate their own cities would enhance the educational value and relevance of the game. The reliance on specific versions of Minecraft and external mods like Forge and CustomNPCs may limit the system's accessibility and ease of use. Future versions should aim for greater compatibility and flexibility.

4.1. Recommendations for Future Work

For further improvements to the game, the world can be auto generated according to the students' city selections. A tool named Arnis has been tested for this purpose (Louis-E, 2022). Since there are no datasets that provide detailed information about the buildings like their color or architecture it is difficult to generate an accurate simulation of the city. That is why in this version of the game this tool was not integrated to the project. However, if further improvements can be made to this open-source tool it can be used in this project as it would improve the real-world experience of the students and take the students' attention towards the game even further.

Further personalization of the game environment could be achieved by allowing players to customize their own cities or towns for simulation. This level of customization would not only make the learning experience more relevant and engaging but also encourage players to consider flood mitigation strategies within the contexts of their own communities. Exploring the potential for a Virtual Reality (VR) version of Floodcraft could offer an unparalleled level of immersion. Allowing students to virtually "walk through" their flood mitigation projects could significantly enhance understanding and engagement, offering a first-person perspective on the effectiveness of various strategies.

Developing community and collaboration tools to support multiplayer interactions would foster a sense of teamwork and collective problem-solving among students. This would be

particularly effective for large-scale flood mitigation projects, emphasizing the importance of collaborative efforts in addressing environmental challenges (Beck et al., 2010). The integration of Floodcraft with educational resources and platforms could offer educators valuable tools for incorporating the game into formal educational settings. Providing lesson plans, activity guides, and assessment tools would facilitate a seamless integration of Floodcraft into the curriculum, enhancing its pedagogical value (Carbonell-Carrera et al., 2021).

Advancing the game's flood simulation mechanics to include more complex hydrological models would offer students a deeper understanding of flood dynamics (Li et al., 2023). Incorporating factors such as soil absorption, urban runoff, and riverbank overflow could enrich the simulation experience, providing a more comprehensive understanding of flooding. Expanding the game to include modules focused on sustainability practices and environmental conservation would complement flood mitigation strategies with important lessons on ecological stewardship. This could help instill in students a long-term commitment to environmental conservation.

Implementing adaptive learning AI could tailor the gaming experience to individual learning paces and styles. By adjusting the difficulty level and providing personalized feedback based on performance, the game could cater to a wide range of learners, ensuring a challenging yet achievable experience for all. Lastly, leveraging Floodcraft as part of a global flood risk awareness campaign, in partnership with environmental and educational organizations worldwide, could amplify its impact. By raising awareness and disseminating knowledge on flood risks and mitigation strategies on a global scale, Floodcraft could play a pivotal role in fostering a more informed and proactive approach to flood preparedness.

5. Conclusion

The development and implementation of the Floodcraft game on the Minecraft platform provides an innovative approach for educating children on critical flood protection methods. Students gain firsthand experience applying essential strategies like floodwalls, sandbagging, wet floodproofing, and elevation by interactive gameplay features simulating real-world flood mitigation techniques. To validate the pedagogical impact of Floodcraft, conducting quantitative tests on learning outcomes and qualitative surveys on user engagement becomes essential. However, existing research on serious games and Minecraft education shows the value of an experiential, simulation-based learning tool for motivating students and enhancing their understanding of complex systems.

Floodcraft can help the next generation to engage in building community resilience to flooding by using a popular and creative tool that younger people highly appreciate. Game-based education in Floodcraft enhances problem-solving skills, raises environmental awareness, and encourages social responsibility regarding flood risks. While the current version focuses on four essential mitigation methods, Floodcraft has the potential to expand and teach additional flood-proofing techniques, safety protocols, and sustainable development practices. Overall, it demonstrates Minecraft's potential as an engaging platform for preparing students to mitigate and adapt to climate challenges and to motivate students to create a safer and more sustainable future.

For future work, several promising directions for further enhancing Floodcraft's educational impact and player engagement have been identified. One potential improvement is the automatic generation of game environments based on the cities selected by players, which could be achieved through tools like Arnis. Despite current limitations due to incomplete data on building specifics, future refinements of such tools could lead to more authentic city simulations. Allowing players to tailor their simulated cities would make the game more relevant and immersive. Additionally, developing a Virtual Reality (VR) version of Floodcraft could revolutionize the learning experience by letting students virtually explore their flood mitigation efforts from a first-person viewpoint.

Furthermore, adding multiplayer features to the game could encourage teamwork and cooperative problem-solving, which are crucial for large-scale flood management. Integrating Floodcraft with comprehensive educational materials—such as lesson plans and evaluation tools—would facilitate its incorporation into school curricula, thereby boosting its educational value. Enhancing the game's flood simulation to include advanced hydrological models would deepen students' understanding of flood dynamics and sustainable practices. Utilizing adaptive learning artificial intelligence could customize the game to individual learning needs and preferences, ensuring it is both challenging and rewarding for all players. Finally, partnering Floodcraft with global environmental and educational organizations could elevate its role in international flood risk education, helping to foster a globally aware and proactive approach to flood preparedness.

6. Data Availability

The codebase is open-source, free to use, and can be accessed on GitHub (https://github.com/uihilab/floodcraft).

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9. CRediT Author Statement

Eslim Emiroglu: Methodology, Software, Visualization, Investigation, Data Curation, Writing – original draft. Cori Ann Grant: Methodology, Investigation. Yusuf Sermet: Methodology, Validation, Conceptualization, Writing – original draft. Ibrahim Demir: Funding acquisition, Conceptualization, Supervision, Resources, Writing – review and editing.

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