

Serious Game on Flood Risk Management

P. Meera, M.L. McLain, Kamal Bijlani, R. Jayakrishnan
and Bhavani R. Rao

Abstract The applications of using serious games as a teaching tool are vast. One of the fields of knowledge that is now being implemented in serious games is Disaster Relief Management. Serious games use a variety of multimedia and strategies that allow the learner to participate in a graphic simulation of a disaster. This work gamifies the topic of flood risk management. Floods are a unique type of disaster in that they have an element of predictability. This predictability can be utilized as a gaming element involving time limits to reduce the amount of destruction and loss of life due to flooding. Of the many benefits of using games for educational purposes, it can help people who live in rural areas who may have limited education comprehend this complex material in a meaningful way. A learning approach called Kolb's Learning Model is used to convey the material. It familiarizes people with the different responses and terminologies of the hazard while achieving high concentration and interest from the learner. After developing this game, the effectiveness of this gaming method is analyzed by a comparative study of text book learning and this serious game.

Keywords Serious games · Flood · Risk management · Disaster management · Kolb's learning model

1 Introduction

Natural disasters are a massive problem all around the world. It can happen because of the natural processes on the earth. Floods, earthquakes, volcanic eruptions, and tsunamis are some of the natural disasters that can occur. Floods are the most

P. Meera (✉) · K. Bijlani · R. Jayakrishnan
Amrita E-Learning Research Lab, Amrita Vishwa Vidyapeetham, Amritapuri, Kollam,
Kerala, India

M.L. McLain · B.R. Rao
Ammachi Labs, Amrita Vishwa Vidyapeetham, Amritapuri, Kollam, Kerala, India

common natural disasters worldwide. A flood is the overflow of water that submerges land [1]. Frequency of worldwide flood disasters is increasing year by year [2], so it is important to plan and construct a safer environment. Taking the correct actions for a disaster management is important. One way this can be achieved is to instruct people who live in flood zones and areas at risk of flooding by offering them specialized courses in flood management. This can help reduce the adverse effects of floods by presenting different disaster risks that require solutions. We can reduce the vulnerability of an at risk location by taking preventive measures such as raising the land, making firebreaks, etc. [3]. Nowadays human activities contribute to these disasters by effecting climate change, deforestation, and reduction of wetlands, which leads to flooding so it is important to have an effective disaster management system. The adverse effects of floods can be reduced through some structural and non-structural measures and should have an established method of disseminating information about flooding. It is essential to this information system is trusted [4]. Often floods can have enormous adverse effects while people are not prepared due to lack of early warning systems, preparedness and mitigation measures. Thus, it is important to educate people about the causes and risks of disasters.

Game based learning is one of the best methods to help people understand a phenomenon. Each participant can experience emotions in a very personal and enduring manner [5]. There are many benefits in game based learning method. It can aid learning to those who have limited education because of its pictorial simulation and display. Also, it can implicitly support the learner to improve their knowledge [6]. Serious games are the best opportunity to learn and experience different flood risk situations and also it provides an admirable motivation and engagement. With the help of serious games complex real life situations can be simulated in a simple manner in the game world. By taking the correct responses at the correct time, we can reduce the causalities of flood disaster. This is done by taking precautions at the right time with the help of various disaster management institutions and also making use of military resources. It will help reduce the potential losses from any harmful hazards and it is important for an effective management of an accident. The player identifies the roles and responsibilities for each member of the community and the preparedness measures. By describing different types of hazards and the preparedness measures can be of both personal benefit and benefit for the community for mitigating the worst impacts of flood disaster. Serious games are the best tool to get insights in decision making also raising awareness for people [7]. Therefore, it will be an excellent tool to look at different future implications and to facilitate the involvement of people in these strategies to initiate some movement during deadlock situations.

The game provides a teaching tool for learning the different phases of flood risk management including Mitigation, Preparedness, Response and Recovery. Then it demonstrates the responses related to the flood. Usually, children and adults are most affected during the flood because of lack of awareness and preparation. In these years floods are becoming a major hazard. The serious game is demonstrating all vulnerable situations and their mitigation methods. The vulnerable situations like soil erosion, evacuation, medical care, and sewage collection and risk awareness.

All citizen have the right to be informed of how to respond to flooding, also ensuring that all the emergency responders have adequate resources and skills. All these issues are demonstrated by this serious game. It will improve the player's ability to respond against any vulnerable situations during disaster.

The rest of the paper is organized as follows, Sect. 2 provides the background studies of flood disaster, Sect. 3, conveys how the system is organized, risk management, Sect. 4 includes the solution approach, Sect. 5 is Result analysis, and Sect. 6 shows the conclusion.

2 Related Works

Several works have been done on disaster risk management. Meesters et al. [8] have proposed a serious game for disaster information management as a team player; each team should manage different scenarios and can communicate each other. As per their research, all the first responders should evacuate people into their prospective shelters. If medical support is needed anywhere, then responders can make use of mobile application provided to the participants by means of proper communications. The study provides methods for evacuating people properly and how to effectively manage information about disasters. The responder should manage available data and experience with real-time feedback. In another study [9], Felicio and the team have introduced a serious game for different disasters. The player should need to select one disaster and then get into the play. But the drawback in this paper is that the graphics are poor and also the game is not user-centric. The Player is unable to Stop or Pause the game and there are no multiplayer and different levels. The Score is another concern. Based on another research work by Syukril et al. [10], the plot's challenges arise as different monsters. The player needs to solve each monster with different challenging environment like puzzles and acquire scores. Each player is acting as a magician. This is an example of active learning; the learner could get knowledge from their own experiences. We evaluated all the existing game based learning method and found out that there is the gap in between the game and the learner. The method of teaching used in our serious game is analyzing the learner capability and to motivate them to take suitable actions on the game through the psychological aspects.

3 System Design

Serious games realize the primary purpose of learning along with entertainment. Kolb's learning model is a four stage learning method. This is used in the game for facilitating the learner in learning. The stages are Experience, Reflection, Conceptualize and Test. Here the serious game is for developing awareness about different vulnerable situations in flood disaster and the mitigation methods. It

reduces the impact of the disaster by allowing people to take proper precautions. The main targeted audiences are students for learning about disaster management as part of their syllabus. In addition to that, it is also helpful for general people who lived in the flood prone area. The people will get awareness and motivate them to make further steps on real time flood disaster. During the crisis, each organizer should be aware about their tasks and responses. The serious game gives awareness for all such responders. An effective learning is achieved by reinforcing the learner for learning concepts and key steps regarding the disaster throughout the game. An exercising method with that is providing an initial experience for the player. In the game, the player would need to identify appropriate resources and to satisfy each and every need regarding a flood disaster.

Kolb's learning model is used to demonstrate the game. In the first stage the player should analyze and identify the risk situation. Then the player finds out the active and proper solution for the risk from the organizers. We provide an information button for the player to observe the nature of that particular area. From that information they will have a perception about the risk of that situation. It will help them to select the proper choice for risk management. In the last phase, we test the knowledge that the learner acquired from the game. A quiz will evaluate the players content acquisition level. Quiz questions are created on the basis of Bloom's Taxonomy for facilitating the cognitive thinking of the learner. The stages of cognitive domain, such as knowledge, comprehension, application and evaluation are used to frame the quiz questions.

4 Solution Approach

When flooding occurs, it involves economic, people and environmental consequences. We are considering all those consequences throughout the game play.

The economic consequences such as

- Repair of roads
- Reservoir destruction
- Electricity and communication
- Bridges
- Salvaging damage to agriculture
- Automobile destruction

Environmental consequences such as

- Water pollution
- Introduces insects
- Soil erosion

People consequences such as

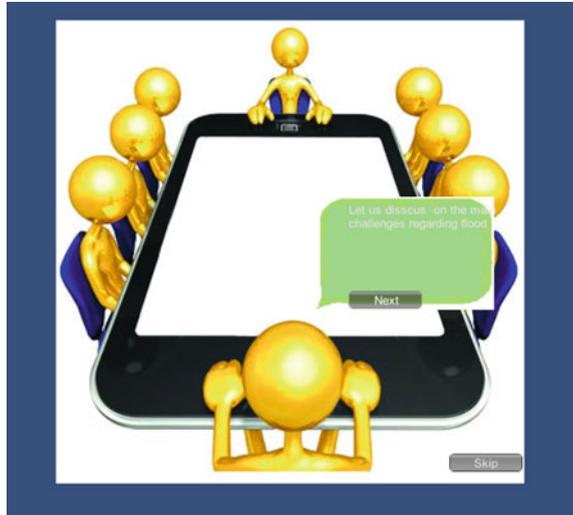
- Flood walls
- Improved early warning

The flood management system has 4 steps such as mitigation, preparedness, response and recovery. The game contains three levels. First level includes mitigation and preparedness. In this phase the player obtains knowledge about the preparedness and mitigation measures of flood disaster. Mitigation is to prevent hazards from developing into disasters. Preparedness measure will reduce the consequences of disaster while they occur. In this, we can focus on long term risk reduction measures like different cropping patterns for reducing crop loss, preventing massive leakage from nuclear plant which causes high radiation in that area, as well as short term measures. The second level conveys the response measures on flood disaster. To take a direct action to save lives, protect property, care for victims, etc. and also mitigate the amount of damage. The third level is the recovery stage. In this, the player takes actions that involve rebuilding destroyed property, re-employment and repair. We are considering a flood prone environment with high population and risks. Figure 1 shows the game flow. At first, the collector in that area is conducting a conference with the main organizers in that area such as health officers, civil engineers, PWD officers, fire fighters, etc. He announces that there is a possibility of flood within 48 h. He then assigns tasks for every member for flood risk management. The fire safety officers should be concerned about fire operations and other accidents, and the medical department should assure the medical support. In the case of bridging of two coastal areas for easy evacuation, the PWD officers will take care about that. Like that each department should do their work properly. Maintenance should complete within the time limit. We are assigning scores for the number of lives saved. If the player loses any lives the score will be reduced. Then the player needs to play the game as each responder. If there is a need for military resources, the player can make use of it. This also increases the score. Then the high



Fig. 1 Architecture of serious gaming for flood risk management

Fig. 2 Game screen shot of group discussion



flooded area could be considered first for getting a good score. The flood will come after the time limit. If the player has overcome the risks, then he is allowed to take a quiz, otherwise we will give them feedback and allow them to play again by resolving problems that he was not able to solve earlier. In the end, we are displaying Score, Feedback and Badges for motivation and reinforcement.

Figure 2 shows the conference with the important organizers as mentioned above. They will discuss the current challenging situations in the city and also discuss the measures that can be used to mitigate them. Risk assessment can be done in this phase as well as taking appropriate actions to reduce the vulnerabilities. First, shows an introduction about that area with population, economic status and percentage of vulnerability. Figure 4 shows the game play scenario. There is a group of organizers and each organizer is assigned to particular tasks. When a popup comes out, the player comprehends the risk situation from the pop-up and selects the appropriate action from the assigned tasks of organizers. If the selection of task is wrong, that will reduce the score and also gives feedback for that response. The popup arises along with a 5 s timer. When the timer completes, the popup will end up automatically. And then shows another risk situation. The player should complete all the risks within 10 min time limit (Fig. 3).

There is a risk bar at the top, which shows the remaining risks. Before 10 min completion, a warning for flood will appear. It also shows some clues for the remaining risks. Once the time completes, the flood will occur. Then, we give feedback about the performance of the player and score. As like this, the player needs to complete level 2 and 3. After that there is a quiz. The quiz is created on the basis of Bloom's Taxonomy, assesses the player content knowledge. Figure 4 shows the quiz after the game play. Through this we can evaluate the player as to whether he is a good player or a weak player. Throughout the game we are



Fig. 3 Identifying risk and taking the appropriate task from the organizer

visualizing Kolb's learning model. Kolb's model includes the phases such as experience, reflection, conceptualize and test. In the serious game, first player experiences the flood risks, then responding to that risk. From this they will get to know about the risk situations and the different mitigation methods.

The evaluation part intends to check whether the player understands the content knowledge. The timing is another important concern. The player should complete almost all the risks within the time limit. So he needs to identify more time consuming and less time consuming work. The serious game has implemented with the help of Unity3D. Unity is a game development ecosystem. It has a powerful

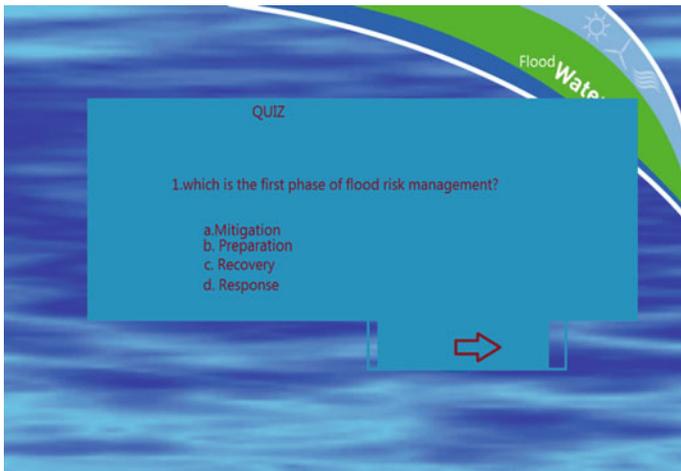


Fig. 4 Quiz after the quiz for checking the content knowledge

Table 1 Comparative study of serious game with text based learning

	Textbook-based learning	Game-based learning
Understandability of the content	Comparatively less	High
Interaction	Tutor-learner interaction	Direct involvement
Real-world experience	Nil	High
Self assessment	Less	High
Motivation	Less	High
Engagement	Comparatively less	High
Effectiveness	Less	High

rendering engine fully integrated with a complete set of intuitive tools and rapid workflows to create interactive 3D and 2D content [11]. It is also an easy multi-platform.

5 Result Analysis

The comparative study of textbook-based learning with game-based learning is shown below in the Table 1. Different factors such as effectiveness, interaction, self-assessment, motivation, experience, understanding and involvement have compared. It has drawn attention to the effectiveness of game-based learning.

A group of high school students was chosen for analysis of the effectiveness of the game. A quiz program was conducted for the evaluation of knowledge acquirement while providing two different resources to learn about flood management. Textbook material and developed game were the two different resources provided to them.

Scrutinizing the results from both learning shows the significance in game based learning. Students answered most of the questions correctly while playing the game as compared to text book learning method. Figure 5 conveys that the learner understands more about the flood management using serious games. Thus, game based learning is one of the best educational technologies for improving quality of education.

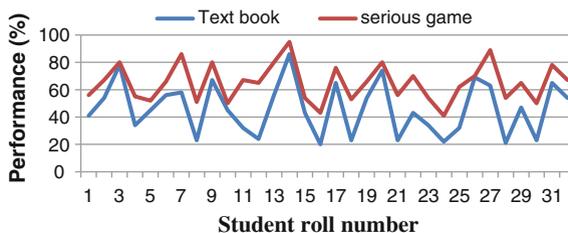


Fig. 5 Analysis of knowledge acquisition

6 Conclusion

The work in this paper shows that serious games can be a very effective teaching tool to convey the process of flood risk management. It can be especially useful to help people learn who have limited education in rural areas at risk. The design of this game explores a flood risk management practice through which it ensures an effective decision making at the time of disaster alert. Through this game, people can develop the confidence to respond to each flood risk. The psychology based learning methods used here: Kolb's model and Bloom's Taxonomy, assure motivation among learners. This also helps to improve the effectiveness of the serious game. The scope for serious game in learning process has been validated by the significant increment seen in the performance of students in the conducted testing phase. With a relatively good accuracy ratio, the game succeeded in providing better awareness and opportunity for understanding the content of the flood management. It helps to prepare, manage, reduce and cope with different risks at the time of flood occurrence.

Acknowledgments We are grateful for the support and facilities provided by the Amrita Vishwa Vidyapeetham University and Amrita E learning Research lab.

References

1. Uche, D.O.V.: The environmental effects of flood disaster in Anambra state. *Pelagia Res. Libr. Adv. Appl. Sci. Res.* **4**(1), 499–505 (2013)
2. EM-DAT: The OFDA/CRED international disaster database: www.em-dat.net, universitecatholique-Brussels-Belgium
3. Xuan, W., Zhao, G.: Early warning monitoring and management of disasters. In: *Proceedings of the Workshop on Applications of Spatial Information Technology on Disaster Prevention and Reduction*, 1-4244-1212-9/07/\$25.00 ©2007 IEEE, 08 Oct 2005
4. Samaddar, S., Misra, B.A.: Flood risk awareness and preparedness: the role of trust in information sources. In: *2012 IEEE International Conference on Systems, Man, and Cybernetics, COEX, Seoul, Korea 14–17 Oct 2012*
5. Barthélémy-Ruiz, C., Carpiér, B., Clément, N.: United nations high commissioner for refugees ©1995. <http://www.unhcr.org/473dc1772.pdf>
6. Soler, J.L., Mendoza, P., Pons-Vazquez, S.: Impact of video games-based learning on academic performance and motivation: a case study
7. Iacovides, I., Cox, A.L.: Moving Beyond Fun: Evaluating Serious Experience in Digital Games, CHI 2015, Seoul, Republic of Korea, Publication rights licensed to ACM, 18–23 April 2015
8. Comes, T., Fiedrich, F., Fortier, S., Geldermann, J., Müller, T., Meesters, K., van de Walle, B. (eds.): Disaster in my backyard: a serious game introduction to disaster information management. In: *Proceedings of the 10th International ISCRAM Conference, Baden-Baden, Germany, May 2013*
9. Felicio, S., Dargains, S.: Stop disasters game experiment with elementary school students in Rio de Janeiro: building safety culture. In: *Proceedings of the 11th International ISCRAM Conference, USA, May 2014*

10. Syukril, M., Pramono Hadi, M., Straatssma, M.W.: Differences in disaster response due to varying data availability a serious game for flooding disaster research in Surakarta, Indonesia. (ISSN 0024-9521, IJG vol. 43, no. 1, June 2011 (49–62)© 2011 Faculty of Geography GadjahMada University the Indonesian Geographers Association
11. Create the Game You Love with Unity: Unity game development engine. <http://unity3d.com/unity>