The Flood Resilience Challenge serious game to teach complex socio-environmental issues in engineering: Extended abstract

1. BACKGROUND

Flooding represents Canada's most frequent and expensive hazard, with its effects anticipated to escalate due to climate change and alterations in land use. Conventional engineering methods excel in addressing straightforward, linear issues, rather than wicked problems such as flooding and climate change [1]. Flood risk management cannot be tackled solely with technical engineering strategies alone because it is embedded in complex social and political issues, and there are many stakeholders with differing, and often competing, perspectives and interests. Engineers hold a crucial position in managing floods, making it essential for them to grasp the socio-environmental implications of their work. Currently, many engineering students do not receive adequate education to comprehend the socio-political intricacies of environmental issues, nor do they have sufficient opportunities to develop collaborative problem-solving skills.

To address this challenge, the online version of the Flood Resilience Challenge (FRC) game was implemented in a large engineering class with over 100 students. The FRC is a serious game which is means its purpose is education rather than solely entertainment [2]. The FRC is an experiment in shifting away from the limitations of traditional engineering educational approaches to flood risk management, such as lecture-style teaching by providing experiential learning, and the online version is an alternative to face-to-face delivery. The purpose of the FRC game is to build the capacity of stakeholders to improve flood resilience and enhance flood risk governance, including collective decision-making, and it does so through: (a) increasing flood literacy; (b) fostering social learning; (c) creating safe spaces for exploring risk management and communication strategies.

The FRC was developed by Dr. Evalyna Bogdan during a postdoctoral fellowship at the University of Waterloo (now at York University), and Heather Jean Murdock who was a practicing hydrotechnical engineer and is currently a PhD student at the University of Potsdam. Although serious games have found application in educational and professional settings within Canada, there has been an absence of a serious game that effectively simulates the types of floods and reflects the Canadian governance framework [3]. Serious games are a recognized method for exploring natural resource management and policies, because these games encapsulate complexity, promote collaborative and reflective learning, and provide environments to practice conflict resolution [4], [5]. This extended abstract is a brief summary: A detailed literature review, game description, and further findings are provided by Bogdan *et al.* [3].

In the FRC game, participants assume the roles of various stakeholders (such as a mayor, prime minister, hydrologist, land developer, etc.) and work together to devise strategies for planning and responding to various flood scenarios. The game is divided into three rounds, with each round comprising four stages. During the first stage, players discuss and combine their resources to select flood mitigation strategies and determine their placement on the map of the fictional Town of Hydrason, which is shown on an online Miro board. The second stage simulates a flooding event. In the third stage, participants use the Budget App to assess costs and damages. The concluding stage involves voting for elected officials (mayor, premier, prime minister). The subsequent rounds prompt players to evaluate their previous choices and decide on new flood risk mitigation measures and strategies. Following the third round, there is a debriefing session where players reflect on their tactics and experiences, enhancing the learning opportunity.

The main research question is 'How effective is the online FRC game as a teaching and learning tool in a large engineering classroom?' The effectiveness of the FRC game is measured by answering the following questions: Were the learning objectives achieved? Were students more engaged by the FRC game than by traditional teaching techniques such as lecturing? Did students make the connection between lessons learned in the game and application to real-life problems?

2. METHODOLOGY

The research question is explored by investigating two main hypotheses: The first hypothesis is that the FRC game is effective in helping students' meet their learning objectives: (a) Increase flood literacy; (b) Better understand differing flood stakeholders' views and power; and (c) Make connections between the game and real-life. The corresponding research questions (RQ) for the first hypothesis are: RQ 1a) To what extent did students' flood literacy increase in terms of concepts in risk, flood risk measures, and impacts?; RQ 1b) Can students better understand different flood stakeholders' views and power dynamics through role-play?; RQ 1c) Did students make connections between lessons learned in the game and application to real-life problems? The second hypothesis is that the FRC role-playing game will increase students' engagement in the classroom through experiential learning. The corresponding research question is: RQ 2) Did students feel more engaged by the FRC game than by traditional teaching techniques such as lecturing and reading?

The FRC game was incorporated into a 3rd year core course in civil engineering with 117 enrolled students taught by Dr. Nadine Ibrahim at the University of Waterloo. Ibrahim emphasizes the topics of systems thinking, decision-making, and project management—the FRC game was linked to the decision-making. Three Teaching Assistants (TAs) were trained as facilitators prior to the game to help facilitate the class (in addition to the 6 FRC Team facilitators) and to support students' preparation which included reading documents, watching a video on how to play the game, and an opportunity to ask questions the week before during an introduction (Session 1) to the game. Students completed an online consent form and pre-game survey. The game was implemented using Zoom for communication (audio, chat, video), the online Miro collaborative whiteboard as the 'gameboard', and a Budget App to calculate costs. Immediately after the last round of the game, students participated in the debrief over Zoom to share their learnings with each other. Students then completed an online post-gave survey. Students played the game over two classes (Sessions 2 and 3) for a total of 1.5 hours each day, 20 students maximum per 'gameboard' and 6 gameboards, 1 in each Zoom breakout room.

Quantitative and qualitative data were collected from students who provided consent for the research components with approval from the University of Waterloo (REB# 43328): pre-game survey (n=52) and a post-game survey (n=14), and from debrief with players (n=60). Ethics approval was not required for students to play the game itself because it was part of the curriculum (but not graded). Survey responses that were left blank were excluded; hence, the total number of responses for certain calculations is under 52 in the pre-game survey and under 14 in the post-game survey. The averages from the pre- and post-game surveys for quantitative data were analyzed to suggest possible changes. However, the small number of respondents

prevents any significant statistical analyses. Future studies will recruit more participants. To evaluate the qualitative data from survey comments and debrief responses, thematic analysis was used. The debrief consisted of questions such as: How did it feel to take on a role or perspective that is different from your own? 3. What are the benefits and challenges of collaboration? What is your main takeaway from playing the game?

The learning theory lenses applied in this research are social learning and experiential learning. Social learning takes place when individuals move beyond their personal viewpoints and interests, including via role-playing, and gravitate towards common goals and the collective good, striving for solutions that are mutually agreeable and more inclusive. Experiential learning, by using real-world examples and hands-on activities, equips students with the skills to apply theoretical knowledge to practical problems across disciplines, enhancing critical thinking and intrinsic motivation, while also fostering deep learning and memory retention.

3. RESULTS

Overall, students found the FRC game as an experiential learning more effective than traditional approaches to engineering education such as lectures and readings. Several types of Likert-type scales were used in the surveys: 1-not at all, 2-slightly, 3-moderately, 4-very, 5-extremely; and 1-very low, 2-below average, 3-average, 4-above average, and 5-very high.

Research Question (RQ) 1a) *To what extent did students' flood literacy increase in terms of concepts of risk, flood risk measures, and impacts?* was divided into three aspects. First, students' confidence in their understanding of the concept of risk and its components (exposure, hazard, and vulnerability) increased by 0.57 from 2.57 (n=51) to 3.14 (n=14) (scale: 1-not at all to 5-extremely). Second, students reported an increase in their confidence regarding their knowledge of flood risk mitigation strategies, with the average rating rising by 0.59, from 2.41 (n=51) to 3.00 (n=14) on a scale from 1 (not at all confident) to 5 (extremely confident). Notably, the proportion of students who felt very confident (rating of 4) in their understanding of flood risk measures surged by more than 40%, moving from 1.96% to 42.86%, following participation in the game. For the third aspect, in the post-game survey, students were asked if the game influenced their ideas on addressing flooding issues with various flood mitigation strategies and their impacts: structural strategies (e.g., dams and dikes) versus non-structural strategies (social mitigation such as regulations, or natural mitigation such as protecting wetlands). Their response (n=14) was an average of 3 or moderate.

Facilitating social learning through methods like role-play and experimentation is vital for jointly tackling flood-related challenges, as it helps in appreciating diverse perspectives and working towards shared objectives. Social learning was explored through RQ 1b) *Can students better understand different flood stakeholders' views and power dynamics through role-play?* The FRC game enhanced students' comprehension of the various viewpoints and values among stakeholders, as expressed here: "Improved understanding of the thought process of other stakeholders as everyone has their own agendas." Furthermore, the game underscored the importance of player interactions in navigating these differences and discovering mutual interests, including the "benefit of planning and collaborating". Students also developed a deeper insight into power dynamics, including the inclusion and exclusion of stakeholders, and the

importance of empathy. A student expressed one of the insights gained as follows: “People with more power can make decisions without consulting stakeholders with less power.”

To explore RQ 1c) *Did students make connections between lessons learned in the game and application to real-life problems?,* we asked several questions. First, how the game affected students’ understanding of flooding issues in the real world. The average score was 2.93 (n=14) on a scale from 1 (not at all) to 5 (extremely), with the majority clustering around 3 (moderately) at 35.71% and 4 (very) at 25.87%, signaling considerable learning. Students were asked how they might apply their learnings to academic or professional work. They acknowledged the importance of engaging a variety of stakeholders and promoting community involvement. Also, students highlighted the dilemmas arising from discrepancies between their personal values and those of their assigned player roles. Such insights are crucial for understanding potential moral and ethical challenges they may encounter in their engineering careers. We also asked whether this game increased their understanding of flood risk governance. The average rating was a 3.54 (n=13) on a scale from 1 (not at all) to 5 (extremely). Over half of the respondents (54.26%) rated their understanding as between 4 (very) and 5 (extremely), highlighting substantial learning gains in flood risk governance. One student commented: “When floods occur, communication can easily break down despite even the best efforts.”

Lastly, we investigated RQ 2) *Did students feel more engaged by the FRC game than by traditional teaching techniques such as lecturing and reading?* Approximately half of the students (n=66 for Session 2 and n=62 for Session 3) out of 117 actively participated in the FRC game, representing an engagement rate exceeding 50%. This marks a significant improvement in engagement relative to the typical participation rates (ranges 21% to 29%) in the synchronous online engineer class. The survey inquired about the effectiveness of the online FRC game as an educational tool through experiential learning (defined as interactive learning that applies theory to real-world scenarios) compared to traditional methods (such as lectures and readings), without specifying what 'effective' meant, leaving it open to students' interpretation. Twelve out of fourteen students, or 85.72%, rated it as either 3 (moderately) or 4 (very) effective.

4. CONCLUSION

As an innovative teaching and learning tool, the FRC increased engineering students’ flood literacy, and understanding of differing perspectives and power. Students made connections between learnings from the game and real-life problems, including raising ethical dilemmas. Thus, the FRC enhanced students’ understanding of the complexity of flooding issues, such as governance and risk management. The online game also increased the number of students engaged. The research findings on the FRC game have relevance for incorporating the FRC game into a range of disciplines focusing on complex socio-environmental problems and for providing engaging online educational activities. The FRC game has been played by students in other disciplines and those working in the private and public sectors. These findings will be published in future work.

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