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Save Our Sea: Game-Based Learning on Sea Environment Care

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Abstract: This study introduces the development and evaluation of a 2D marine pollution awareness game to address the pressing issue of marine pollution. The study addresses the challenges associated with raising awareness about marine pollution, including the lack of knowledge and awareness among the general public regarding the impact of marine pollution on the environment. The lack of effective educational tools and resources to communicate the complexities of marine pollution poses a significant problem. To tackle these issues, the study aims to develop a 2D marine pollution awareness game that not only educates but also engages players in a meaningful way. The game's objective is to educate players about the environmental impact of marine pollution while engaging them through interactive gameplay. The Rapid Application Development (RAD) methodology involved designing the game's mechanics, graphics, and audio elements using tools like Construct, Aseprite, and Canva, followed by usability testing using the Game Experience Questionnaire (GEQ). The findings indicate positive feedback from participants, highlighting high levels of immersion and positive affect, but also suggest areas for improvement in terms of the challenge level and flow. Future work includes enhancing the game's challenges, adding multiple languages for broader accessibility, and exploring the integration of VR/AR technologies to enhance educational impact. This study underscores the potential of the game as a tool for environmental education and conservation, with opportunities for further development and impact in raising awareness about marine pollution.

Keywords: *Marine pollution, Awareness game, Game-based learning, Environmental education.*

1. Introduction

Annually, humanity generates over 430 million tons of plastic, with approximately two-thirds consisting of short-lived products that quickly turn into waste, leading to the contamination of oceans and potentially entering the human food chain. (UNEP, 2023). According to WWF, about 60% of global marine plastic enters the ocean from China, Indonesia, Malaysia, the Philippines, Thailand and Vietnam (WWF, 2020). Based on a study conducted by the Centre for Marine and Coastal Studies (CEMACS) at University Sains Malaysia, Malaysia holds the highest rate of plastic consumption in Asia, with a rate of 62 kg per capita per year, and ranks eighth globally in terms of plastic pollution (Hamid & Che Din, 2022). Fauziah et al. (2021) also suggest that the quantity of waste that effectively reaches the ocean could be high. However, further efforts are necessary to fully investigate and document the extent of this issue.

Although society has been making efforts to decrease the use of single-use plastics in recent years, the COVID-19 pandemic has caused a setback in plastic management. The issue has been worsening by the exponential increase in the consumption of single-use plastics, including personal protective equipment like masks and gloves (Patrício Silva et al., 2021). Plastic waste will continue to pose a significant and persistent problem for the marine environment. According to projections, plastic pollution in the oceans is expected to triple by 2040 if current trends continue (Harvey, 2020).

Abalansa et al., (2020) report acknowledges the issue of marine plastics pollution as a global environmental problem and recommends a trans-disciplinary approach, involving all types of stakeholders. The availability of waste collection bins can affect people's behavior towards water pollution. To address this issue, policymakers should increase awareness of water pollution and consider situational factors when designing and implementing policies (Okumah & Ankomah-Hackman, 2020). Increased public awareness of microplastic

pollution caused by inappropriate disposal of sanitary products down the toilet is necessary due to the global distribution and projected growth of the non-woven textile industry (Ó Briain et al., 2020).

The study reported an average score of 9.69 out of 20 points among Hong Kong University students on a multiple-choice ocean science quiz about general marine environmental knowledge, with 50% of students scoring 9.5 or higher. In comparison, 27.12% and 22.87% of students scored the highest and lowest average scores of 16.33 and 5 points, respectively, indicating a good overall understanding of general ocean science topics but lacking knowledge in specific areas such as ocean-carbon relationships, primary oil pollution sources, plastic pollution, and ocean-technology relationships (Mallick D et al., 2023). Malaysia is the 8th largest producer of mismanaged plastic waste globally and has an estimated annual input of 140-370 million kilograms of plastic waste into the ocean, while also lacking information on the levels of microplastic pollution in the environment (Chen et al., 2021). The newspaper report suggests that the ban on single-use plastic straws by several state governments in 2019 was ineffective due to a lack of awareness of the plastic problem, suitable alternatives, and citizen participation in interventions, while highlighting the lack of knowledge of plastic pollution among most respondents, leading to poor practices despite a relatively higher attitude (Chin, Mahanta, & Nath, 2023).

To increase engagement and knowledge, additional measures may be necessary. Research on game-based learning (GBL) methods indicates that they can enhance students' motivation and learning outcomes in higher education settings (Jääskä et al., 2022). The use of games that incorporate environmental education has shown an effective solution to addressing the issue (De Oliveira Pantoja et al., 2019). The research aimed to assess the effectiveness of the educational game quiz Assistance in enhancing cognitive abilities and critical thinking among higher education students, with results indicating that game-based learning proved highly effective in improving learning outcomes (Wardoyo et al., 2020). According to the results of the post-test data reported by Harsono, Sanjaya, & Harnadi (2021), the game effectively generated an environment where people were more attentive to the issue of water pollution. Game-based learning fosters collaborative and stimulating activities, creating student-centered learning environments that promote the cultivation of students' mental and psychological well-being and the development of soft skills in a dynamic, entertaining, and creative manner (Lampropoulos et al., 2019).

The significance of this game lies in its potential to contribute to the larger goal of addressing the issue of marine pollution and protecting marine ecosystems. By educating and engaging young adults about this important issue, the game can inspire them to take action and make a positive impact in their communities and beyond.

In addition, the use of multimedia elements in the game can enhance the learning experience and make it more accessible to a wider audience. By making learning about marine pollution more engaging and interactive, the game can encourage players to explore the issue in more depth and develop a deeper understanding of its causes and consequences.

Overall, the project is significant because it can help raise awareness about marine pollution, promote sustainable behaviors, foster empathy for marine organisms and their habitats, and inspire action to protect the marine environment. By doing so, the game can contribute to the larger goal of creating a more sustainable and environmentally conscious society. This project will be of great benefit to young adults, environmental organizations, educators, and communities by providing an engaging and interactive tool for learning about marine pollution and its impact on the environment.

2. Literature Review

Marine ecosystems, known for their vast size (Jha, 2004), play an important role in Malaysia, with many islands, coastal areas, and seas supporting a wide range of marine biodiversity (Ching, 1998). In Malaysia, the coastal area is a significant contributor to the country's ecotourism sector (Hassan, 2008). The increasing pollutants and global changes worldwide are causing alarming negative impacts on the biodiversity of living organisms, raising concerns among the scientific community regarding different types of pollution (biological, chemical, and physical) and the resulting changes at the species and community levels (Aless, Gallo, & Tosti, 2015).

Over time, Malaysia's marine environment has been consistently troubled by a major issue primarily caused by water pollution. Marine pollution, caused by human activities, entails altering the natural state of the ocean, damaging the marine ecosystem, and introducing harmful substances into the marine environment. The ocean is increasingly facing serious pollution issues, with chemicals and garbage being the two main types of pollutants flooding its waters. Table 1 shows the types of marine pollution and the source of pollution (Zheng and Liu, 2021)

Table 1: Causes of marine pollution

Types of Marine pollution	Source of Pollution
Human activities produce garbage	Industrial waste
	Household garbage
	Medical waste
	Land source input
	Coastal tourism
White pollution	Ship transportation
	Fishing and breeding
	Atmospheric deposition
	Domestic garbage and sewage
Ship pollution	Cruise ship
	Solid waste
	Oily sewage and toxic gas
	Tanker
	Shipwreck(oil spill)
Exploration of marine oil and gas resources and mineral resources	Development and mining of solid mineral resources
Land reclamation	Land reclamation
Pollution in the mariculture industry	Nutrients
	Sulfide
	drug
New estrogen pollution	Industrial production
	Human activity

(Source: Zheng & Liu, 2021)

Traditional awareness campaigns are failing to engage a diverse audience in the face of the growing threat caused by marine pollution. These days, innovative alternatives like games and social media campaigns are becoming effective tools. Through the use of technology, art, and digital platforms, these strategies hope to engage a larger audience and promote awareness of the urgent need to address marine pollution.

In recent years, social media platforms such as Twitter and Facebook have played an important role in campaigns and initiatives that seek to engage individuals in addressing environmental issues (Alves et al., 2016). Social media has emerged as a powerful and accessible platform for raising awareness and facilitating discussions on various subjects, including social and public health issues, with the average daily usage increasing over the years. People's usage of social media and content-sharing platforms like Facebook, YouTube, Twitter, and TikTok continues to grow each year, with increasing amounts of time spent on these platforms (Madhumathi et al., 2021).

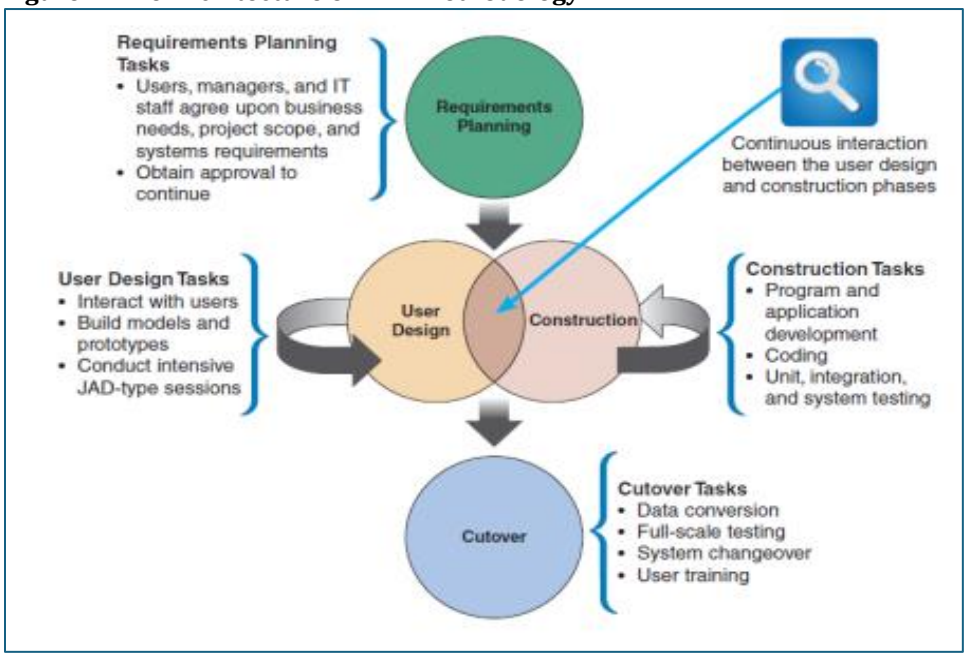
Social media usage has become widespread, with the average person spending 2 ½ hours daily on social platforms, around 4.2 billion people using social media (55% of the global population), and increased usage during the COVID-19 pandemic, particularly among teenagers. The analysis of social media's impact on opinion, knowledge, and behavior indicates that while it can raise awareness and promote environmentally friendly behavior, it can also lead to opinion silos and reinforcement, presenting both positive and negative implications for environmental issues like climate change (Mavrodieva et al., 2019). Figure 2.3 shows the banner Save the Ocean Using social media with the #CleanSeasPhoto Challenge that has been posted to social media.

Zargham et al., (2019) conducted a user study involving 21 participants, comparing a game to two other models, an animated serious video and a humorous animated video. The study found that the game-based approach was more effective in engaging users and raising awareness of the topic. The results of the Martins et al., (2020) study suggest that individuals perceive the game as an immersive and engaging medium for interaction, considering it a creative and entertaining way to engage in events. Youth, specifically those aged 11-15, are attracted to video game features such as visually appealing graphics, captivating sound effects and design, impressive visual effects, and engaging animations (Evans et al., 2013). In an experiment involving undergraduate students, the proposed approach to cultural study was found to be effective in enhancing players' cognitive growth and increasing awareness (Chai-Arayalert & Puttinaovarat, 2021).

3. Methodology

Rapid Application (RAD) is used in this project as the methodology for developing this game application. The RAD methodology is a software development approach that prioritizes creating prototypes rather than extensive planning. Instead of spending a lot of time on upfront planning, the RAD Model aims to develop software quickly within a short period (Martin, 2020). According to Triana, Gunawan, Prasetyo, and Pangestu (2020), while it typically takes at least 6 months to build an application, using the RAD method can allow for completion within a shorter timeframe of 1 to 3 months. The RAD methodology prioritizes a faster development cycle with higher quality results compared to other methodologies, with less focus on planning and greater emphasis on continuous development. Figure 1 shows the architecture of the Rapid Application Development methodology (Arisandy & Rudi, 2021).

Figure 1: The Architecture of RAD methodology



(Source: Arisandy & Rudi, 2021)

The RAD methodology is adapted to this project because it offers quick iterations and valuable user feedback. It enables developers to make frequent changes and improvements to the game based on feedback from users, such as educators and students. By quickly iterating and actively seeking input, the game can effectively deliver the intended learning objectives and engage the players. This iterative approach ensures that user suggestions can be incorporated, and any potential issues or concerns can be addressed throughout the development process, resulting in a more polished and impactful learning experience.

The RAD methodology is known for its ability to deliver projects in a short period of time. In the case of this small-scale game-based learning project, which is limited in scope, timely delivery is essential. With RAD,

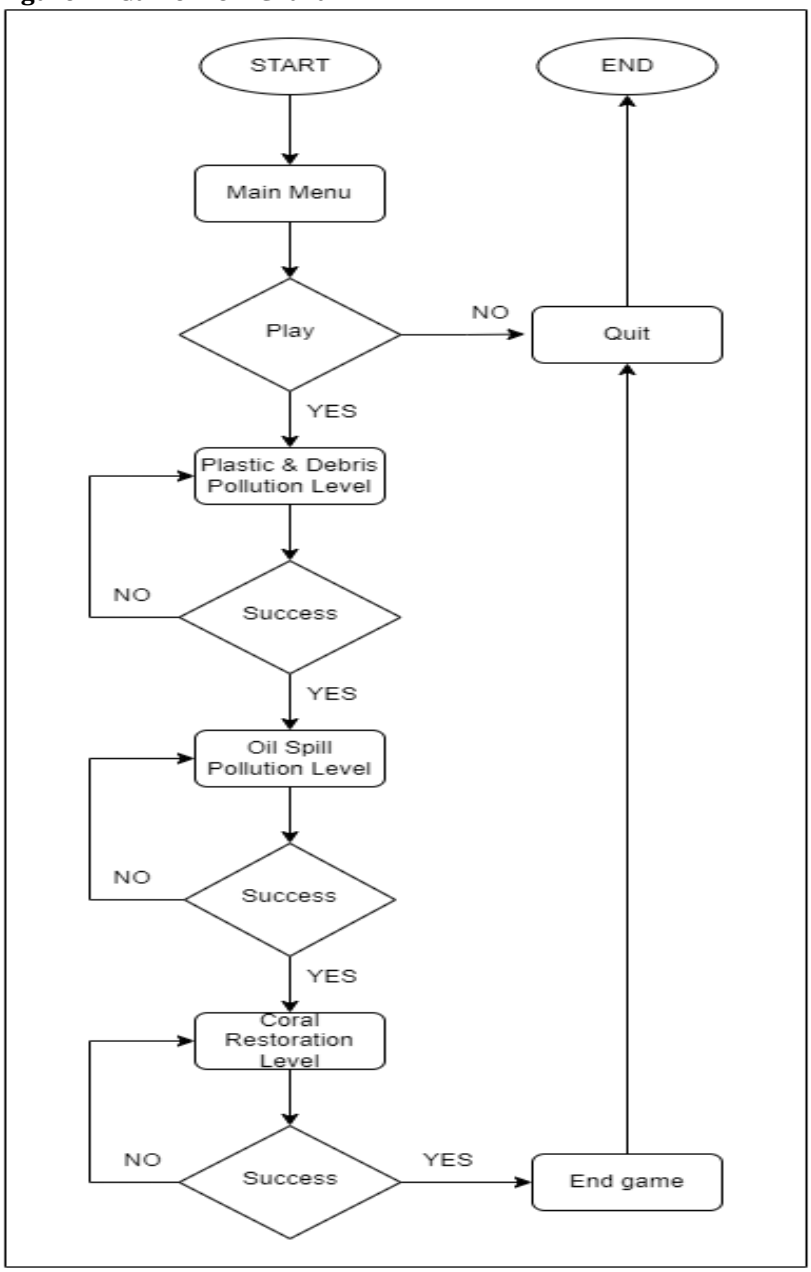
developers can quickly prototype, validate ideas and iterate on game mechanics and educational content. This iterative approach ensures projects stay on track, minimize risk and maximize efficiency. By accepting RAD, the project can be managed efficiently, leading to the delivery of high-quality games within the given timeframe.

Since the project will be developed solely by one developer, the potential negative effects of miscommunication and different project directions, which can be more common in large-scale projects with multiple team members, are significantly reduced. With a single developer, decision-making and coordination becomes more streamlined, allowing for a smoother development process.

4. Results and Discussion

In this section, the game design is shown through a flowchart. Figure 2 shows the game's overall flowchart.

Figure 2: Game Flow Chart



Next, below is the high-fidelity storyboard for the developed game. The storyboard comprises nine scenes and the description along with the multimedia elements are provided for each scene.

The game's flow, represented by three levels, guides players through diverse aspects of marine pollution. Level 1 emphasizes proper trash disposal in a cleanup mission, Level 2 involves addressing oil spills and rescuing trapped animals, and Level 3 focuses on coral restoration amidst challenges. Educational pop-ups enhance environmental awareness, ensuring a cohesive and impactful gaming experience with a structured progression.

Level 1: Plastic and debris

In the first part of the game, players take on the role of a character charged with cleaning up marine pollution and use the WASD keys to move through a dynamic marine environment. Level 1 is primarily concerned with gathering and classifying different kinds of trash, in particular plastic and debris, into orange, brown, and blue color-coded recycling bins. As players advance in the game, educational signs revealing facts about marine pollution are introduced. This adds an educational dimension to the immersive experience. In addition to involving players in a practical cleanup mission, this interactive role-playing game format instructs them on the importance of proper trash disposal and the damaging effects that marine pollution has on the ecosystem. Figure 3 shows the level 1 interface, Figure 4 shows the recycle bins interface.

Figure 3: Level 1 Interface

Figure 4: Recycle Bins Interface

Level 2: Oil Spill

In Level 2, players take on the difficult task of cleaning up pollution caused by oil spills. They do this by using the well-known WASD controls to guide their character through a dangerous aquatic environment. The main goal is to gather oil spills that have been scattered across the water while avoiding different obstacles. One special feature of this level is that it gives players the option to save animals that are stuck in the oil spill, which gives the mission a more compassionate feel. Players have to use strategy to control the collected oil spills because a full tank requires a trip to a recycling or sell point. Throughout the game, educational pop-ups promote awareness and comprehension of this environmental issue by giving crucial information about the causes and effects of oil spills. Figure 5 shows the level 2 interface.

Figure 5: Level 2 Interface

Level 3: Coral Restoration

In Level 3, players take on the crucial task of restoring coral reefs by using drag-and-drop features to bring damaged reefs back to life. Players carefully restore the coral's health by using brushes, nutrients, and more tools. Players face obstacles like fishing boats that endanger coral and marine life, including fish and turtles that are particularly vulnerable, while on the restoration journey. Random debris surfaces add complexity and pose a direct threat to the fragile coral ecosystem. Managing these risks requires quick thinking and calculated action. At the same time, educational pop-ups enhance gameplay by providing insightful information about the wide range of threats that coral reefs face and their profound significance. In addition to involving players in a practical conservation endeavor, this immersive restoration adventure promotes increased awareness and environmental consciousness. Figure 6 shows the level 3 interface.

Figure 6: Level 3 Interface

The Game Experience Questionnaire (GEQ) is used in the assessment to determine how satisfied participants are with their overall gaming experience. Participants actively interact with the game during testing, completing tasks to identify possible usability problems and offering insightful feedback. The information acquired from the GEQ questionnaire helps to improve the functionality and design of the game, guaranteeing that it successfully raises user awareness and understanding of issues related to marine pollution.

In this study, a sample of over 30 individuals, mainly categorized as young adults with ages ranging from 18 to 26 years old, participated in the data collection process. Additionally, participants aged over 26 were also included in the study group. Every participant answered the 33 items in the core module of the Game Experience Questionnaire (GEQ) and the 17 items in the post-game module of the GEQ. After that, the collected responses were organized and exported to an Excel file, which made the questionnaire analysis that followed easier.

Analyzing the responses to the Game Experience Questionnaire (GEQ) requires a detailed look at all the different aspects of the player's experience. The entire gaming experience, emotional reactions, gameplay dynamics, presence and immersion, and the enjoyment factor in the learning environment are all evaluated in this thorough assessment. An examination of the participant-completed questionnaires might provide insightful information about the game design's advantages and disadvantages. In addition to providing an in-depth view of the effectiveness of various elements, game mechanics, immersion features, and the learning components integrated into the gameplay, this approach to analysis helps identify areas that require improvement. Through this analysis, a deeper understanding of the player's experience is achieved, providing important information that can inform future game development projects and contribute to ongoing research efforts in the field.

The process of calculating each component score from the items in a Game Experience Questionnaire (GEQ) necessitates a systematic approach. Each component, such as immersion, competence, flow, negative and positive affect, and challenge, was identified and evaluated within the questionnaire. Each component usually consists of several items designed to gauge different aspects of the player's experience. IJsselsteijn et al. (2013) have provided guidelines that contain references to all of these items. Tables 2 and 3 present the results of all calculated items, organized into their respective components for a clearer understanding of the different elements of the player's experience.

Table 2: Results Score from Calculated GEQ Core Module

Components in GEQ	Average Score
Competence	3.32
Immersion	3.72
Flow	2.65
Challenge	2.22
Negative Affect	1.45
Positive Affect	4.09

Table 3: Results Score from Calculated GEQ Post-Module

Components In GEQ	Average Score
Positive experience	2.98
Negative	2.19
Tiredness	1.36
Returning to reality	2.43

The analysis of the Game Experience Questionnaire (GEQ) Core Module results reveals valuable insights into various dimensions of the player's experience. The participants' responses are categorized into different components, each providing a distinct perspective on their engagement with the game.

The high scores in **Immersion (3.72) and Positive Affect (4.09)** indicate that participants were deeply immersed in the game and experienced predominantly positive emotions. These outcomes suggest a successful integration of immersive elements, contributing to an enjoyable gaming experience.

On the other hand, the scores for **Flow (2.65) and Challenge (2.22)** suggest that participants may have found the game less challenging or encountered disruptions in the flow of gameplay. This indicates potential areas for improvement, emphasizing the need for adjustments in-game dynamics to maintain a more balanced challenge level and a smoother flow.

The score for **Returning to Reality (2.43)** highlights a transitional challenge for participants leaving the game environment. Enhancements to the post-game experience or debriefing process may be considered to facilitate a smoother transition from the virtual to the real world.

The score for **Competence (3.32)**, while reasonable, suggests room for improvement. Evaluating specific aspects of competence within the game could enhance player skill development and satisfaction.

The low score for **Negative Affect (1.45)** is positive, indicating that participants did not experience a significant negative emotional impact. However, further exploration is needed to understand the context and reasons behind any negative effects, ensuring a comprehensive understanding of player emotions during gameplay.

Similarly, the low score for **Tiredness (1.36)** suggests that participants did not report high levels of fatigue, indicating that the game did not overly exhaust them physically or mentally.

As a whole, an analysis of the Game Experience Questionnaire (GEQ) Core Module outcomes reveals aspects of participants' interactions with the game that are both beneficial and positive. The success of immersive elements in enhancing the gaming experience is shown by the high scores in Immersion and Positive Affect. But Flow and Challenge both have room for improvement, indicating that the dynamics of the game may need to be changed. The Returning to Reality score highlights the transitional challenge and emphasizes how important it is to improve post-game experiences. Although competency scores make sense, additional assessment could improve the development of skills. While low ratings for negative affect and fatigue are encouraging signs,

obtaining qualitative data would provide a more in-depth understanding. This thorough analysis guides specific adjustments meant to maximize the game design for a more enjoyable experience.

5. Conclusion and Recommendations

Creating a two-dimensional video game is an innovative approach to address the urgent global issue of marine pollution awareness. The Rapid Application Development (RAD) methodology, which allows for quick iterations and employs informative user feedback, is an example of the dedication to a productive development cycle. The creative application of programs like Construct, Aseprite, and Canva improves the game's aesthetic appeal and creates an engaging learning environment for players.

The implementation of the Game Experience Questionnaire (GEQ) as a means of collecting data is crucial for the project has a lot of potential as an engaging and interactive way to raise awareness about marine pollution because of its unique game design. This iterative approach not only enhances the educational aspect but also ensures that the game remains relevant and effective in addressing the evolving challenges of marine pollution awareness.

Recommendations

There are several potential improvements and directions the project could go in the future. To keep players interested and promote a more engaging learning environment, adding more challenges and a variety of activities to the game is an important factor to take into account. Longer user engagement can be ensured by the project by adding new elements that make the gameplay more complex.

Moreover, adding multiple languages to the game presents an interesting opportunity to increase its accessibility. The game's educational impact could be expanded and diversity encouraged by effectively communicating safety messages to users with varying language backgrounds through the translation of the content into multiple languages.

In terms of future development, investigating modern technologies like augmented reality (AR) and virtual reality (VR) offers a fascinating path. By incorporating these technologies, the project's performance as a tool for spreading awareness may be increased by providing users with a more engaging and interactive experience. Investigating VR and AR has the potential to give awareness campaigns new dimensions by offering creative approaches to user engagement and education.

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