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Usability Evaluations of a Water Quality Awareness Game

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Completed Research

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Abstract

Citizens are not aware of water quality issues and their impact on the environment. It was this finding that motivated a project that aimed to design a game to educate users on water quality issues. Design Science Research (DSR) methodology was adopted for the development of the water quality awareness game, which focuses on ocean plastic pollution. This paper reports the usability of the game and the increase in knowledge and awareness of ocean plastic pollution of users. The main findings revealed that whilst initial knowledge of ocean plastic pollution was low among the participants, their knowledge increased after playing the game. The participants found the game to be "enjoyable", "informative" and "eye opening", but that they would have preferred more variability in difficulty levels. This study provides valuable lessons learnt and demonstrates that gamification can be used to educate citizens of water quality.

Keywords

Water quality, awareness, serious game, plastic pollution, evaluation.

Introduction

Water quality issues are serious issues of which citizens are not aware of (Islam, 2008; Karataş & Karataş, 2016; Scholtz, 2018; Yurttaş & Sülün, 2010). A low level of awareness among citizens is concerning as it may result in a behavior that reflects a disregard for the environment and as such, there is a critical need to promote the awareness of water quality issues and its environmental impacts (Yuniato, 2012). A serious game can be used to instill individuals with the necessary knowledge and increase awareness, which may ultimately change behavior, and prevent further damage to the environment (Hadzigeorgiou & Skoumios, 2013). A serious game is defined as a complete game that was designed to achieve a specific purpose other than entertainment (De Gloria, Bellotti, & Berta, 2014; Kiryakova, Angelova, & Yordanova, 2018; Susi, Johannesson, & Backlund, 2007). It combines a "serious" issue with a game that aims to develop user's skills and knowledge through educational content that is implicit in the gameplay (Stege, Van Lankveld, & Sproncj, 2010). The combination of educational content with the element of fun has been proven to draw attention, increase engagement in a specific topic and incite a positive attitude and behavioral change (De Jans, Van Geit, Cauberghe, Hudders, & De Veirman, 2017). Serious games thus provide creative and entertaining platforms through which citizens can be educated and awareness can be promoted.

Ocean plastic pollution is one water quality issue that is deserving of increased citizen awareness. With an equivalent of a truck load of plastic entering the ocean every minute (Pennington, 2016), and the increasing possibility that by 2050, plastic will outweigh fish in the ocean (Cronin, 2017), plastic pollution is currently the oceans greatest threat (Musau, 2017). The effects of ocean plastic pollution are greatly felt by the ocean's inhabitants such as sea turtles, whales, dolphins, and seals. These marine animals along

with many others, ingest plastic as they mistake it for their real food (Barone, 2017; Eriksen et al., 2014; Sigler, 2014). Sea turtles for example commonly mistake plastic bags for jellyfish, a staple food of theirs. Marine animals may also get entangled in plastic, which could ultimately lead to strangulation. Plastic also releases toxic chemicals into the ocean, which further affects the growth and reproduction of marine animals (Bernstein, 2009). It is thus evident that ocean plastic pollution has profound impacts on the environment and is deserving of increased citizen awareness to address such issues and prevent further devastation.

The research and development methodology used for this project is the Design Science Research (DSR) methodology. The low level of citizen awareness coupled with there being no existing applications that promote the awareness of water quality issues in an enjoyable and engaging manner was further explored during the first DSR activity of Problem Identification. Once the problem was clearly identified, requirements were gathered and proposed as part of the second DSR activity. According to the requirements, the game should focus on plastic pollution, and educate its users on the environmental impacts of plastic pollution in oceans and how ocean plastic pollution can be prevented. The game should also be enjoyable and engaging to use. As part of the Design and Development DSR activity, the requirements were used for the design and formative evaluation of three initial prototypes. The findings from these DSR activities were published in (Van Der Merwe, 2018a, 2018b).

This paper presents the final activities of the DSR methodology, where the serious water quality awareness game was developed, demonstrated and evaluated. The developed game consists of three scenarios that aim to promote the awareness of various impacts of plastic pollution in oceans. The game furthermore underwent two types of evaluations: formative and summative. In the formative evaluations, the game was demonstrated to and evaluated by three expert evaluators. The feedback received from these evaluations were used to make further improvements to the game, resulting in another iteration of the DSR Design Cycle. Summative evaluations of the improved version of the game were conducted with 12 target users. One limitation was that the sample size of 12 students in one higher education institution could be considered relatively small. However, the findings still contribute to an understanding of the benefits and challenges of using serious games to create water quality awareness. This study will offer the potential for using a serious game as a tool for educating citizens of water quality issues and a means to reduce plastic pollution.

The structure of the paper is as follows: the research design is reported on in Section 2. The implementation of the project and the iterations are discussed in Section 3. This is followed by Sections 4 and 5, which report on the evaluations and the results of evaluation respectively. This paper is concluded with Section 6, which discusses conclusions and recommendations.

Literature Review

Water Quality Services

The South African Department of Water and Forestry defines water quality as the physical, chemical, biological and aesthetic properties of water. These properties are used to measure the water's condition and determine its fitness for use in a variety of areas. Safe water is a basic human right (Sershen et al, 2016). The United Nations General Assembly declared the access to safe and clean water for human consumption a human right in July 2010 (United Nations, 2011). However, many years later, water of safe quality is still denied to billions of people. According to a report conducted by the United Nations Children Fund and World Health Organization (United Nations, 2017), 2.1 billion people do not have access to safe drinking water and 4.5 billion do not have access to safe sanitation. The low access to safe water is because reliable household water connections are inaccessible to most of the world. Sources that supply water of safe quality is especially scarce in developing countries. Many developing countries therefore rely on freshwater resources (Sidani & Youssef, 2016). However, the continuous degradation of water quality in rivers, lakes and groundwater has too become a global concern (Behmel et al., 2016). In South Africa, "the availability of water of acceptable quality is predicted to be the single greatest and most urgent development constraint facing South Africa" (Blignaut & Van Heerden, 2009). Water pollution is

defined as the undesirable occurrence of effluents entering into a water system, resulting in the change of water quality (Alrumman, El-kott & Keshk, 2016). The influences polluting water are widespread and include human and animal waste, agricultural pesticides, industry waste and plastic (Derraik, 2002; Sigler, 2014).

Nearly one-third of plastic produced is used to make single-use plastics (DiGregorio, 2012). Single-use plastics includes straws, food containers, bottles and bags as most of these products are used once and are thrown away. One such single-use plastic is plastic bags of which 500 billion are produced annually (Sigler, 2014). Plastic popularity is owed to its lightweight, tough and low-cost properties (Derraik, 2002; Sigler, 2014). It is unfortunately the same properties of plastic that allow it to travel long distances and become a problem pollutant (Derraik, 2002; Sigler, 2014). The major concern with plastic is that it does According to a report conducted by Mitchell (2016), the problem of plastic pollution is already so severe, that emphasis must be on prevention. Raising citizen awareness of water pollution is of great importance for prevention (Karataş & Karataş, 2016).

Citizen Awareness of Environmental issues with Gamification

Promoting awareness of environmental issues and preservation is urgent as the level of environmental awareness among citizens is low (Yurttaş & Sülün, 2010; Islam, 2008). A study conducted by Islam (2008) emphasized the low awareness of citizens. Raising citizen awareness of water pollution is of particular importance (Karataş & Karataş, 2016), as many people are not aware of the impact of pollution, whether it be health or environmental risks. Li et al. (2016) also found that the issue of ocean plastic pollution is not familiar to citizens. A targeted and creative approach is needed to engage citizens and promote awareness of environmental issues. Gamification and serious games provide creative and entertaining platforms through which citizens can be educated and awareness can be promoted. Gamification is a platform, which could also be used to pro-mote the awareness of water quality issues and its environmental impact, the proposed system will take the form of a serious game, since serious games are complete games that were designed to achieve a specific purpose other than entertainment (De Gloria, Bellotti, & Berta, 2014; Kiryakova, Angelova, & Yordanova, 2018; Susi, Johannesson, & Backlund, 2007). A serious game is focused on developing the user's skills and knowledge through educational content with element of fun that is implicit in the gameplay.

Research Design

The DSR methodology was selected as the research and development methodology for this project. The DSR methodology is an iterative problem-solving model that aims to create innovative artefacts to solve real-world problems (Hevner & Chatterjee, 2010). This methodology consists of three research cycles and six activities that are to be performed in every DSR project. The first two papers reported on the first three activities of problem identification, objectives of a solution and design and development (Van Der Merwe, 2018a, 2018b). These are briefly recapped below.

i. Problem Identification is the first activity of DSR, which aims to identify the problem to be solved. Paper 1 introduced the problem addressed by the research and reviewed the relevant literature to understand the state of the problem.
ii. Once the problem was identified, the Objectives of the Solution were conducted. Paper 1 proposed a set of requirements for the proposed artefact needed to resolve the problem identified in the first activity. These requirements were updated and verified in Paper 2.
iii. Design and Development is the third activity in which the artefacts desired functionality was determined, and the development of the artefact commenced. Paper 2 introduced initial prototypes and reported on the artefacts development.

This paper reports on the final three activities of the DSR Methodology, which are Demonstration, Evaluation, and Communication.

iv. Demonstrating the efficiency of the artefact to solve the problem. This activity is covered in part in Section 3 as the development, prototyping, and ensuring that it can deliver on its objective.
v. Evaluating the artefact to determine if it fulfils the objectives of the study. Evaluations are reported in Section 4 of this paper.
vi. Communication is the final activity of DSR. The evaluation activity consolidates the results of the research study, deviations noted and opportunities for further work on the research topic.

Demonstration

This section describes the implementation of the serious water quality game. The following subsections highlight the implementation activities.

Iterations

DSR requires extensive testing and evaluation of the artefact, which calls for multiple iterations of the Design Cycle and results in a dynamic ever-changing artefact (Hevner & Chatterjee, 2010). The first and second iterations were previously reported on in prior research (Van Der Merwe, 2018b). They are briefly recapped below, followed by the most recent iterations.

The first iteration of the development of the game involved the creation of an initial screen design (Prototype 1). The researcher demonstrated the prototype to two expert evaluators within the Computing Sciences department at the Nelson Mandela University (NMU). These evaluators are considered experts as they are very knowledgeable or skilful in the development of computer games. The purpose of these evaluations was to receive feedback for the prototype and to discuss the functionality of the game in terms of its goals and challenges. Based on the feedback received, a second iteration of the Design Cycle was initiated. During this iteration, a second and third prototype was created to incorporate the suggestions received from the evaluations.

The second and third prototypes (Prototype 2 and Prototype 3) took the form of storyboards. These prototypes were evaluated by target users of the game to determine which design was preferred by the majority. The differences in each prototype related to the challenges and goals of the game. Prototype 3 was ultimately favoured by the users. This iteration initiated the development of the game.

The third iteration of the development process began with a heuristic evaluation of the developed game. A heuristic evaluation refers to a usability inspection method whereby experts are guided by a set of usability principles and evaluate whether user-interface elements, such as menus and navigation structures conform to tried and tested principles (Preece, Rogers, & Sharp, 2015). Nielsen's heuristics, which contain ten well-known and established principles for usability testing were used for the game's heuristic evaluations. Three experts (n = 3) from NMU's Computing Sciences' department were selected as expert evaluators for the heuristic evaluations. The evaluators made use of a five-point severity rating scale to rate the severity of the usability problems encountered during the heuristic evaluations (0 – not a problem, 1 – cosmetic, 2 – minor, 3 – major, and 4 – catastrophic). Table 1 shows the maximum severity rating from the evaluator's ratings for each heuristic.

H1	Visibility of system status	1
H2	Match between the system and the real-world	1
H3	User control and freedom	2
H4	Consistency and standards	1
H5	Error prevention	0
H6	Recognition rather than recall	0
H7	Flexibility and efficiency of use	2
H8	Aesthetic and minimalist design	1
H10	Help and documentation	2

Table 1. Severity measure

None of the heuristics were identified as being major problems. The results from the heuristic evaluations were used to improve the game to address the identified issues. Usability problems relating to terminology and the placement and colours of objects were easily and quickly rectified. A more significant issue was noted in one of the game's scenarios. The movement of the character in Scenario 1 was too sensitive to the keyboard arrow keys, which made the scenario too difficult to complete. The controls were made less sensitive as to make the scenario game passable but still challenging. The game's user interface was also modified to reflect a more minimalist and aesthetic design. General feedback of the game received during these evaluations was positive, with one evaluator mentioning how "impressed" they were with the design and animations of the game. The third iteration delivered a version ready for summative evaluation.

Game Design Elements

Every element of the game, from the scenarios to the characters aims to educate the user on ocean plastic pollution. These game design elements are grouped and reported according to the Serious Game Design Assessment (SGDA) Framework (Roungas & Dalpiaz, 2016). This framework outlines six essential elements for the design of a serious game (Van Der Merwe, 2018a) i.e. purpose; content and information; mechanics; fiction and narrative; aesthetics and graphics; and framing.

Purpose:- The purpose of the serious water quality awareness game is to promote the awareness of ocean plastic pollution and its environmental impacts. The game consists of three scenarios that aim to promote the awareness of the various issues caused by plastic in oceans through gameplay and quizzes. The three objectives are: plastic ingestion by marine animal (in scenario 1 of the game), release of plastics toxic chemicals and other environmental impacts (in scenario 2 of the game), and plastic entanglement and strangulation of marine animals (in scenario 3 of the game)

Content and information:- The game's content includes all the information, data and facts provided and used in the game. All the information and facts provided in the water quality awareness game are related to ocean plastic pollution and its environmental impacts. Each scenario takes place in a different ocean. The scenario descriptions that are observed by the users at the start of each scenario provides information on the three worst oceans containing the most amount of surface plastic pollution. During gameplay, each scenario also provides information on distinctive environmental impacts through fact panels and quizzes. The game thus aims to provide the user with a wide range of knowledge related to various impacts of ocean plastic pollution as to encourage a greater understanding of the severity and complexity of the issue.

Game mechanics: are the methods or rules of the game invoked by the players to interact with the game world. The game mechanics used by the water quality awareness game are: 3-seconds count down which allows the player to get in position; 4-directional arrow keys to navigate; three heart shaped lives icons that decreases to zero as player loses; health bar that decreases as the animal swims and touches a plastic; sea shells increase the health and speed of the marine animal; plastic objects which the player must avoid hitting not to decrease health bar; and maps positioned on the top right-hand corner of the screen illustrates where the player is in the ocean. In addition to the game mechanics are: the scenario mini-quizzes consisting of five true or false questions related to the specific scenario, which the player must answer to get to the second scenario, and the final quiz which consists of 20 questions, which are a combination of true or false and multiple choice

Fiction and narrative: this consist of the characters, narrative, setting, story, scenario, back story and problem for the game play. The game consists of three scenarios. According to Gray (2016), the three worst oceans that contain the most amount of surface plastic (ranked from least to most plastics) are the North Atlantic Ocean (Scenario 1 in the game), the Indian Ocean (Scenario 2 in the game), and the North Pacific Ocean (Scenario 3 in the game). The game also consists of three characters, a fish, sea turtle and whale.

Aesthetics and graphics: this refer to the sounds and visual components used by the game designer. The background music used in the scenario games mimics the sound of the ocean. Sounds are also used to indicate to the user when they did something right or wrong. For example, if the user answers falsely to a true statement during the scenarios' true or false mini quizzes, a deep low-pitched sound will be played indicating that it was the incorrect answer.

Framing: the sixth design element refers to framing the first five design elements in connection with the target group. The user profile for this game is the university students who are between 18 and 25 years of age (Van Der Merwe, 2018b).

Evaluation

Participant – Profile, Tasks and Procedure

The effectiveness of usability testing relies greatly on the test participants (Tullis & Albert, 2013). The selection of participants must be based on a user profile that reflects the characteristics of the potential

users of the system. Nielsen (2000) suggested that five participants are sufficient for discovering 80% of usability problems; however a later study (Hwang and Salvendy, 2010) recommends a sample size of 10±2 participants. For our study, twelve participants were therefore selected and convenience sampling was used. Six of these participants had prior background knowledge on ocean plastic pollution as they were enrolled for the EIS module, which is a Computing Sciences Honours module at NMU. These six students may thus form a biased sample, which is a short limitation of this study.

The participant profiles are shown in Table 2. The sample included eight male participants (67%) and four female participants (37%). All participants (100%) are postgraduate students, over the age of 21 with 3+ years of computer experience, which shows a high level of IT literacy and computer ability. All participants (100%) have also used a gaming system before, which would allow them to compare their experiences with a standard game. Six participants (50%) were enrolled for the Environmental Information Systems (EIS) module.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Gender	Male	Male	Female	Male	Male	Male	Female	Male	Male	Female	Female	Male
Gaming Experience	3+	1-3	1-3	3+	3+	3+	1-3	3+	3+	3+	3+	3+
Enrolled for EIS	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No

Table 2. Participants' profile

The participants were required to attempt all three of the games scenario's, as well as the final quiz. During the summative evaluation sessions, the researcher provided the participants with a brief overview of the research study. Afterwards, the participants were briefed on the procedure of the evaluation and provided with a pre-study questionnaire that aimed to measure their current pre-study knowledge of ocean plastic pollution. The participants were then provided with a set of tasks to guide them through the evaluation. On completion of the tasks, the participants were instructed to complete the post-study questionnaire.

Evaluation Criteria and Research Instruments

Summative evaluations were conducted to determine the usability of the game and the increase in knowledge and awareness of ocean plastic pollution of users. The pre-study questionnaire was the first questionnaire to be completed by participants. It consisted of a 5-point Likert scale, which the participants could use to rate their current knowledge of water quality issues, water pollution, and ocean plastic pollution. This questionnaire also consisted of 15 true or false and multiple-choice questions, which aimed to measure the participant's current knowledge of ocean plastic pollution.

On completion of all the tasks within the game, a post-study questionnaire was administered to the participants. This questionnaire consisted of six sections. The first section collected biographical information, such as gender, age, and gaming experience. The second section consisted of the same questions asked in the pre-study questionnaire, which was used to measure their knowledge after completing all the tasks. The third section aimed to evaluate the usability of the system. The evaluation criteria focused on the two non-functional requirements of the game, engagement, and enjoyment. These criteria were used to evaluate whether the game fulfils its two non-functional requirements (NFR) of being engaging and enjoyable. In the last section of the post-study questionnaire, the participants were asked to list the most positive and negative aspects of the game as well as any additional comments.

Analysis and Communication of Results

The data from the summative evaluations were collected using paper-based questionnaires. The results of the evaluation are discussed in this section, along with whether the game fulfils the requirements identified in the previous report (Van Der Merwe, 2018b).

Knowledge Contribution Assessment

Before commencing with the tasks, the participants were required to rate their current pre-study knowledge of water quality issues, water pollution and ocean plastic pollution using a 5-point Likert scale ranging from 1 to 5, where 1 represents None and 5 represents Expert. Statistical ranges were applied to the data to categorize the responses as none [1 to 1.8), limited [1.8 to 2.6), neutral [2.6 to 3.4), very good [3.4 to 4.2) and expert [4.2 to 5]. Table 3 shows the aggregated results of the pre-study knowledge rating results from all participants.

	Sample Size (n)	Mean (μ)	Min	Max	Mode
Water Quality Issues	12	2,58	1	4	2
Water Pollution	12	3,08	2	4	3
Ocean Plastic Pollution	12	2,92	2	4	2
Overall	12	2,86			

Table 3. Pre-study knowledge rating results

The aggregated mean shows that the participants pre-study knowledge of water quality issues, water pollution and ocean plastic pollution were neutral (μ =2.86). With regards to ocean plastic pollution, the majority of participants specified their pre-study knowledge as limited. After completing the tasks within the game, the participants were asked to rate their knowledge of water quality issues, water pollution, and ocean plastic pollution for the second time. Table 4 shows the aggregated results of the ratings from all participants.

	Sample Size (n)	Mean	Min	Max	Mode
Water Quality Issues	12	3,83	3	4	4
Water Pollution	12	3,92	3	5	4
Ocean Plastic Pollution	12	4,08	3	5	4
Overall	12	3,94			

Table 4. Post-study knowledge rating results

Table 4 shows that the participants rated their post knowledge more positively (μ = 3.94); this is particularly so for ocean plastic pollution, which the game focused on (μ = 4.08). The higher rated knowledge is supported by their post-study quiz results. The participants scored much more positively (μ = 12.71), with the average equating to 84.7 percent. Although the participants who were enrolled for the EIS module covered ocean plastic pollution briefly during the course of the module, their background knowledge did not result in greater quiz marks than those who did not do the module.

Table 5 shows the aggregated results of the pre and post-study quiz results. Before completing the tasks within the game, the participants scored low in the quiz (μ = 6.88), with the average equating to 45.9%. This low result corresponds with the participant's low ratings of their knowledge of ocean plastic pollution and confirms what literature says about citizens having a low level of awareness of ocean plastic pollution. The same quiz was completed after the participants had completed all of the tasks.

	Mean (μ)	Min	Max	Mode
Pre-Study Quiz Results	6,88	5	10.5	6.5
Post-Study Quiz Results	12,71	10.5	15	12
Difference	5.83			

Table 5. Pre and post-study quiz results

Usability Results

The games NFR's were used as the criteria for measuring the usability of the game. The results of the ratings per criteria are summarized in Table 6.

Enjoyment: The findings indicate an overall positive rating (μ = 4.45) for enjoyment. The positive response shows positive usability of the game in terms of these criteria. The highest rated criterion was altruism (μ = 5.00); increasing users concern for marine animals is the main purpose of the game.

Although challenge is the lowest rated criterion (μ = 3.67), it is still in the positive range. It can, however, be induced that a game with greater difficulty levels may be preferred.

	Sample Size (n)	Mean (μ)	Min	Max	Mode
Enjoyment					
The game promotes the welfare of others (marine animals).	12	4,75	4	5	5
The game increases the users concern for others (marine animals).	12	5,00	5	5	5
The game has variable difficulty levels.	12	3,67	2	4	4
The game is at times challenging.	12	3,92	3	5	4
Related information is organized based on scenarios. Each scenario provides information on different topics.	12	4,92	4	5	5
Overall	**12**	**4,45**			
Engagement					
The game is adaptive (E.g. the user is able to easily adjust to each scenario)	12	4,42	3	5	5
The experience of learning about a serious issue while playing a game is enjoyable and amusing.	12	4,25	2	5	5
Each scenario contains a unique goal, which is clearly defined.	12	4,58	4	5	5
The user receives prompt feedback from the game.	12	4,67	3	5	5
By taking on the role of various marine animals, the user is able to better understand the challenges that they face.	12	4,58	4	5	5
The instructions of each scenario are clearly explained.	12	4,42	2	5	5
It is clearly shown when a user has successfully or unsuccessfully completed a scenario.	12	5,00	5	5	5
It is clearly shown when a user has successfully or unsuccessfully completed the whole game.	12	4,92	4	5	5
Overall	**12**	**4,60**			

Table 6. Usability of the Game

Engagement: - The findings also indicate an overall positive rating for engagement (μ = 4.60), which is the second significant NFR of the game. The highest rated criterion is win-states (μ = 5.00). The game thus successfully shows users when they have successfully completed a scenario. The lowest rated criterion is fun (μ = 4.25). This result, however, is still very much in the positive range.

Effectiveness and learnability: The effectiveness criterion included the metric task completion and learnability included time on task. During the evaluation all participants could successfully complete each task without any errors or assistance. The task time was measured by timing each task with a timer and noting the time stamps of each participant. The participants were instructed to indicate to the evaluator when they started a task so that the evaluator could record the time for each task as accurately as possible. The time it took for each participant to complete each scenario was noted and the average time for each task was calculated.

Overall, Scenario 1 had the longest completion time of 6.35 minutes, while Scenario 3 had the shortest completion time of 3.54 minutes. The completion time for scenario 2 was 4.76 minutes. This steady decline in time indicates that as participants completed each scenario, they got used to it and they could complete the subsequent scenarios much easier and faster, even though the difficulty level increased from Scenario 1 to Scenario 3.

Analysis of Additional Feedback

The last section of the questionnaire allowed the participants to provide additional feedback with their experience of using the game. The participants' comments offered insight into the usability issues as well as the strengths and weaknesses of the game. Using theme-based content analysis (Neale & Nicholas, 2001), which is a method for identifying, analyzing and reporting relative themes within a data collection,

the researcher grouped the comments according to common raw data themes that emerged from the participant's responses.

There were eight usability issues noted by the participants. The most significant problem was with the navigation, with two participants struggling to navigate through the oceans and one noting a lag in the system response time. The participants also expressed their satisfaction with the game by identifying numerous positive points. The positive points were content (very informative), enjoyment (enjoyable game), feedback (immediate feedback kept the users engaged), positive aesthetics (makes learning interesting) and visual design (pleasant interface). The most interesting positive theme of the game was its ability to provide knowledge and promote the awareness of ocean plastic pollution and its impacts, which was the primary purpose of the game. The participants described the game as "very informative" and "eye opening". The participants furthermore showed appreciation for the enjoyment of the game, with several stating that the game is "fun", "enjoyable", and "easy to play", which was a functional requirement of the game.

Conclusions and Recommendations

In conclusion, the primary purpose of this paper was to measure the usability of the water quality awareness game and the increase in knowledge and awareness of ocean plastic pollution of the users. The results found that the initial level of ocean plastic pollution was low amongst the sample tested. Although the sample was small, they were an educated sample with half also having background knowledge of ocean plastic pollution. The level of awareness amongst other samples may thus be even lower. This result confirms the literature findings that citizens have a low level of awareness of water quality issues, such as that of ocean plastic pollution.

The SGDA Framework was successfully used to guide the requirements to design and implement the game. The games NFR's were used as the criteria for identifying the game's usability problems. It is evident from the results that there are no major usability problems. If the game were, however, to be developed further, it should include greater difficulty levels as this was a minor usability issue identified. The game was however proven to be enjoyable and engaging, which were the two main NFR's. Future work identified during the evaluations could include a fourth scenario that includes a mixture of all three scenarios, fact panels, which includes a text-to-speech reader and longer quizzes.

Two limitations were the small sample size of 12 students in one higher educational institution. The six students who were enrolled for the EIS module, which briefly covered ocean plastic pollution could possibly form a biased sample, which is also a short limitation of this study. However, this study successfully demonstrates the concept of gamification as a tool for creating awareness of water quality. Based on the results found, this research and development project fulfilled its purpose of promoting awareness of ocean plastic pollution in an enjoyable and engaging manner. This research and development project fulfilled an identified need of using serious games to promote the awareness of environmental issues, such as that of water quality.

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