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Identifying and validating game design elements in serious game guideline for climate change

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ABSTRACT

Climate change can simply be defined as an increase in temperature, normally referred to as global warming. Recent studies have confirmed the failure of many climate communication efforts due to the one-directional transmission of information that has transformed the audience into passive consumers of information. The young generation tends to be avid gamers, thus serious games could be a suitable medium to increase climate change awareness in order to cultivate a better attitude towards nature among this group. However, very few games focus on carbon cycle fundamentals that are directly related to climate change. Existing climate change games have been unable to improve the quality of knowledge on environmental issues due to the lack of contextualization of the carbon cycle. Thus, the purpose of this study was to develop and verify a guideline of game design elements to assist game developers in developing a climate change game that can facilitate experiential learning on climate change based on the carbon cycle. The guideline consists of 13 game elements derived from previous studies. Seven experts from both game and environmental areas were selected to review the designed guideline. The experts were given two to six weeks to evaluate the guideline and were asked to rate and comment on each game element. At the end of the review, the experts' feedback and comments were analysed and scrutinised. The results showed positive feedback from all experts. The guideline was updated based on the experts' comments, and finally a total of 12 game elements for a climate change game remained. This guideline can be applied to develop a new climate change game. This paper discusses the validation of the guideline proposed for a climate change game design.

1. Introduction

Greenhouse gases, massive rainfall, and marine life extinction are the climate change (CC) issues impacting the world. Unfortunately, many still do not consider them to be serious. World nature organisations and individuals have taken various actions to resolve these worldwide CC issues. It may take millions of dollars in funds and probably another decade to restore the quality of the earth. Still, a much bigger challenge is to educate people to be more responsible towards nature. To create public awareness, everyone needs to understand the main natural environmental processes, based on the carbon cycle. Once the carbon cycle is understood, people will be more aware of the factors that cause CC rather than simply focusing on each separate issue in CC. Nevertheless, it is important to focus on the message to be delivered and how to deliver the

message so it can be easily understood. The next challenge is to ensure that the message is relatable to daily activities. One of the ways that could be effective in converting the message is via serious game usage. Serious games have been found effective as teaching tools as they provide live experiences. Recently, many serious games on CC-related issues have been developed. However, most CC games have been designed as mini online games such as puzzles and trivia or simple simulations that involve hand-and-eye coordination. The existing CC games cover environmental issues, such as recycling, reducing waste or sharing transportation that could immediately affect the environment. No current games highlight the underlying concerns of CC through contextualization of the carbon cycle. Thus, there is a need for a CC game that can educate people about the importance of the carbon cycle during gameplay. This is because a game can be a medium to create awareness, change players' behaviour

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and provide entertainment throughout the learning process (Alonsofernandez et al., 2017). Therefore, the aim of our research was to design a game using the carbon cycle as the game content. In this paper, we present a guideline and its verification to assist game developers in developing a CC game. The guideline describes the design of game elements that should be included in the serious game for climate change. The game elements are identified based on similar studies and verified through experts' validation.

This paper is divided into several sections. In section 2, the game and gamification are differentiated while in section 3, the literature review on the carbon cycle and climate change issues is discussed. Section 4 contains further literature analysis of existing CC games. Apart from this, section 5 shows the methodology used in this research and the CC design guideline developed. The findings of this research are shown in section 6. The experts' evaluation of the 13 climate change elements is discussed and finally, section 8 concludes this paper. The limitations and future works are also stated in section 8.

2. Game vs gamification

Games can be designed solely for entertainment or for a primary purpose like education, training or creating awareness. Games with these purposes are also known as serious games. Players need to be able to enjoy the game, whether it is designed for entertainment or specific purposes. Equally important is to make sure the players understand messages designed in any serious game. Current games in the market for entertainment like PUBG and Mobile Legends, as well as serious games like Minecraft and The Sims receive endorsement from players for their remarkable design. Hence, the design elements have been adopted not only by other games but also by non-game applications.

Many applications (shopping, entertainment and bill payment apps) have been designed and developed for their specific purposes using game elements implanted in the design. For example, points will be awarded to the users if they are willing to rate items that they purchased through a shopping application, which is similar to an in-game reward system. The same goes for bill payment applications that reward consumers who pay on time by providing coupons and vouchers. Some entertainment applications use rank; to categorize users based on their activities and support towards the applications. This is the concept of gamification (rewards, rank, etc.) which is applied in non-game applications and believed to increase users' engagement and loyalty. Although there are authors who do not differentiate between game and gamification, our stand is that these two terms differ, and more effort is involved in developing a game compared to gamifying an application. Applications with gamification features and games are both designed with different approaches and aims. The objective of this research is to identify and validate the elements of game design in serious game for climate change, and not for gamification.

3. The carbon cycle and climate change issues

Climate change can simply be defined as the increase in temperature normally referred to as global warming. This high temperature has led to an enormous loss of ice in Antarctica. The ice in this region has been dissolving and observed to stop growing in the past 40 years (Stroeve and Notz, 2018). This phenomenon has caused elevated sea levels, which, in turn, has significantly degraded land areas. Some big cities, including New York in the USA, Honolulu in Hawaii, and Park Royal in Jamaica (Hartig et al., 2002), may be completely submerged underwater. Subsequently, the shrinking of land area directly causes the loss of homes, history, and culture for many civilisations and living creatures around the affected area. This chain of incidences also triggers many other destructive phenomena, such as natural hazards and the tragic death of animals.

The main question on everyone's mind should be how the temperature has reached such high extremes. The scientific answer to this question can be found in the carbon cycle itself. The carbon cycle is the recycling of carbon atoms that repeatedly shift from the atmosphere into the earth. Human and natural activities like respiration, decomposition, burning of fossils fuels and factory emission produce carbon dioxide (CO_2) in the atmosphere while plants assimilate CO_2 via photosynthesis. Excess CO_2 in the atmosphere is the main reason for the extreme heat affecting the whole world (Omer, 2008; Diffenbaugh and Scherer, 2011; Patz et al., 2014). Figure 1 shows the four important elements (carbon, plants, and human and natural activities) in the carbon cycle. There is a need to control CO_2 production to reduce the overall temperature. Unfortunately, many documentaries have reported that human activities contributed to the increase of CO_2 levels by over 400%.

The world population must understand the core concept of the carbon cycle in order to cultivate a better attitude towards nature. Recent studies have confirmed the failure of many climate communication efforts due to the one-directional transmission of information that has transformed the audience into passive consumers of information (Ouariachi et al. 2017). Digital adverts like videos that contain CC awareness messages on Facebook and YouTube showed a slight positive effect. However, the researchers were unable to measure attitude/change in opinion (Goldberg et al., 2021). The young generation, specifically the millennials, tend to be avid gamers. They belong to the digital generation that is always online and quickly adapts to new technology. Thus, campaigns using printed material normally fail to grab their attention.

4. Serious games for climate change

Nowadays, playing games is not only a leisure activity; it has also become a career for some people. The rapid growth of the game industry has encouraged the design and development of more games to suit the players' interests and needs. This need goes beyond entertainment necessity, merely covering the essentials of education, training, creating awareness, and other numerous serious reasons. Serious games are not designed purely for entertainment, but to permit users to learn by experience as they aim to achieve goals beyond playfulness. Minecraft, for instance, is a successful serious game that was designed for educational purposes and has been able to grab players' attention while helping them express their creativity (Melián Díaz et al., 2020). Minecraft shows positive evidence that serious games with a playful design can improve students' understanding and performance in urban planning (Brand and Kinash, 2013), biology (Kipnis, 2018) and cultural heritage (Craft, 2016). Another serious game called The Sims simulates reality in which players learn social interaction and various sciences (Ahmed and Sutton, 2017). Since The Sims portrays real life, pollution is included as one of the game's contents, creating awareness of climate change among its players. However, The Sims is not designed to focus on climate change issues, so many other concerns are not addressed.

4.1. Climate change (CC) game

A study on an international climate politics simulation game has shown that the game can facilitate experiential learning regarding the difficulties of international climate politics. Game players improve their understanding of CC mitigation and personal responsibility, making them more optimistic about international cooperation in climate politics (Meya and Eisenack 2018).

There are many serious games that deliver messages on environmental issues, however, most existing CC games or games related to the issues are mini online games such as puzzles and trivia, mostly aimed at children. Very few games focus on the fundamentals of the carbon cycle that are directly related to the CC. Table 1 presents an analysis of the existing serious games for climate change in the market. The table also lists the four elements of the carbon cycle in the existing games. A CC game should be designed to focus on fundamental issues, including human activities that cause imbalances in the carbon cycle. Climate change games such as ECO, produced by Strange Loop Games in 2017, is a simulation survival genre that includes only some parts of the carbon cycle in the game. The game failed to improve the players' knowledge on environmental issues (Fjællingsdal and Klöckner, 2019). Additionally, the Urban Climate Architect game by Games4USustainability did not include the carbon cycle (but has natural elements, like plants) and was also found incapable of allowing players to gain substantial insights into complex environmental systems (Gerber et al., 2021). Carbon Command and Carbon Runner, both developed by Green Ninja in 2018, are mini games designed for young kids. Meanwhile, Climate Cards and On Thin Ice do not focus on the carbon cycle, so the respondents/players were found to be only slightly engaged with the games (Foltz et al., 2019). Many CC games focus on climate protection, with a major focus on greenhouse gas reduction technology, while even fewer games have considered adapting the carbon cycle in climate change (Reckien and Eisenack 2015). Thus, when designing a CC game, one of the requirements is to contextualise the carbon cycle in its entirety and to make it the main game storyline.

4.2. Game design element

The ability of a game to convey useful information to players is not solely dependent on a captivating design but also on the accuracy of the game content itself and how it is represented to the players. Game developers are concerned about providing accurate information to the players (Foltz et al., 2019). The game's effectiveness will be enhanced by a combination of good design and context. According to Foltz et al. (2019), a simulation type of game is especially well suited to communicating the complexities of climate change because it allows for the simulation of a complex system and allows players to interact with the system. People can be educated about the carbon cycle and climate change through games. People can also have fun while learning so that they do not feel pressured to process the information through the game. According to Sailer et al. (2017), the aesthetic value and quality of design implementations in game design can affect the satisfaction of players' psychological needs. Table 1 shows that games such as On Thin Ice, Climate Cards and Urban Climate Architect are examples of simple yet meaningful games that explain the effects of global warming on the earth through the game. A fundamental requirement for a CC game is a combination of aesthetic pleasure and good information on the carbon cycle in its entirety. Hence, climate change games need to have the game elements of aesthetics and scope.

Furthermore, players must be motivated to play the game on their own accord. Without motivation, players will abandon the game, and the game will fail to achieve its goal. Enjoyment is effective in motivating players' willingness to learn while playing serious games, expectations of usefulness and ease of use are. As a result, serious games should be fun and engaging (Iten and Petko, 2016). Incorporating quizzes into the game may increase the players' motivation and understanding of the issues that the game focuses on. A quiz game can be used to enhance the process of reflection, which is regarded as an important link between learning and knowledge (Videnovik et al., 2018). As indicated in Table 1, games that applied quizzes in their design were Carbon Runner and Carbon Command. These games also reward the players if they answer correctly. For this reason, game elements such as quizzes and rewards must be implemented into the game in order to stimulate players' motivation and understanding.

Moreover, character design is important because the character serves as an ambassador for the message and idea that the game designers wish to present (Zufri et al. 2016). According to Zufri et al. (2016), in-game characters represent players as a part of the game, and its success is usually determined. For instance, Carbon Runner and Carbon Command use 'Green Ninja' as the game's avatar while Oxygen Not Included provide 'duplicants' as the avatar. Players' emotional states must be considered when designing CC games because they are the factors that promote player engagement. According to Sekhavat (2019), a rewarding mechanism is an important part of game design that can directly affect gaming experience in order to promote the desired behaviour in serious games. The rewarding framework can improve the players' playing experience because it affects their emotional state and behaviour (Sekhavat 2019). To stimulate desired learning outcomes, the use of design elements, such as narrative context, rules, goals, rewards, multisensory cues, and interactivity, seems necessary (Dondlinger, 2014). Therefore, CC games require rewarding elements, rules, and goals to improve players' emotional state and behaviour.

Studies have investigated issues of game content design, specifically the player-environment relationship. Normally, the environmental design is set to the environmental mode as a backdrop, resource, enemy, or text. However, previous studies mainly focused on game frameworks and aesthetic pleasure, but not how the games can deal with CC. Current games may raise awareness on certain issues, but the gameplay is limited to board games or computer games, with players confined only to their rooms. CC games should, however, blend real-world and digital elements to provide concrete actions that will give players an enhanced gaming experience and thus lead them to take up tangible actions. The game design determines its usability and effectiveness in providing a satisfactory user experience that will, in turn, lead to achieving the game goals. Requirement elicitation should involve a content analysis of the game goal, narrative content, rules, scope, genre, aesthetic, quiz, reward, challenge, and rank.

This paper presents a guideline developed for CC games to educate people about the carbon cycle concept. The 13 elements gained from further literature review are 1) Goal, 2) Narrative Content, 3) Rules, 4) Scope, 5) Genre, 6) Aesthetic, 7) Character design, 8) Game Mode, 9) Game Level Design, 10) Quiz, 11) Reward, 12) Challenge, and 13) Rank, as shown in Table 2. This table also presents the validation methods used by various researchers to verify these game elements. Most of the studies use the expert review method or questionnaire analysis.

5. Research methodology

The study was divided into three parts: conceptualisation, validation and analysis. The first part involved identifying the criteria for CC game design based on similar studies. The criteria for CC game design include i) game design elements and ii) CC issues. The second part involved validation of the game design elements, and the third part involved the analysis of the experts' feedback.

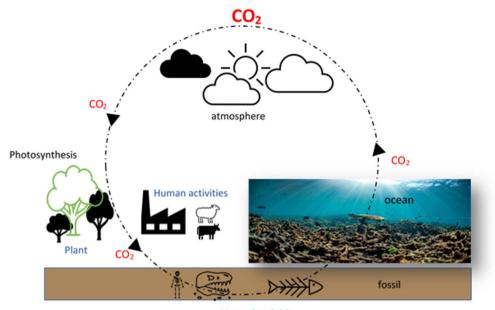
5.1. Part 1: conceptualisation

A checklist containing both criteria was developed based on the gathered information, as shown in Table 2. Thirteen game elements were identified from previous similar research and existing games in the market. The first column in the checklist indicates the game elements, while the second column explains each element based on evidence from the literature review. The final column contains the designed descriptions for the climate change game elements.

5.2. Part 2: validation

The second part of the methodology is the validation process, where seven experts were consulted to confirm the designed checklist. According to some studies, five to seven experts, using a rating scale, is sufficient to rate the domain content. The experts in this study were selected based on their expertise in CC issues and game design, as their opinions were very much needed to cover both areas of concern. It is important to select experts from the focus areas (De Jans et al., 2017). The seven experts were as follows:

- i) Expert 1 a Professor in Marine Pollution and Environmental Forensics
- ii) Expert 2 a Professor in Landscape Studies and Conservation Geology



Natural activities

Figure 1. Elements of the Carbon cycle; Carbon (CO₂), plants, human and natural activities.

- iii) Expert 3 an Associate Professor in Waste and Environmental Management System
- iv) Expert 4 a Doctorate in Game Design with more than 10 years of experience
- v) Expert 5 a Doctorate in Game Engine with more than 10 years of experience
- vi) Expert 6 a Doctorate in Game Design with 10 years of experience
- vii) Expert 7 a Doctorate in Game Design with 10 years of experience

The experts were given a CC game design checklist and two weeks to complete the evaluation. The checklist contains information in Table 2 with two more additional columns. In one of the added columns, the experts were required to rate the items using a 5-point Likert scale to indicate the level of agreement with the value distribution used in the Likert Scale (1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = $\frac{1}{2}$ Agree; 5 = Strongly Agree). In the other column, the experts were encouraged to give extended comments if necessary. The checklist contained 13 items on game elements, and the method to evaluate the checklist was adapted from Nielsen and Molich (1990) and Khowaja and Salim (2018). Their method emphasizes experts' evaluation by identifying issues, and encourages experts to suggest ideas and opinion. Various researchers in their studies applied similar a method to validate the game elements (Ouariachi et al. (2019), Isa et al. (2019), Kou et al. (2016). All experts completed the evaluation within the required time, and their responses were analyzed.

This research carried out content validity assessments to measure the appropriateness of the suggested elements. Prerequisites of assessment can be performed by running the content validity method. This method indicates whether an element can be measured well, or whether potential biases may occur. The Content Validity Index (CVI) method was used to calculate the CC game elements' content validity in this research. According to Zamanzadeh et al. (2015) the I-CVI can be obtained by dividing the number of experts that rated the elements as relevant by the total number of experts.

5.3. Part 3: analysis

The third part of the methodology is the descriptive analysis process. The experts' feedback was analyzed in order to verify the CC Game checklist. The consensus among the answers was measured using the Interquartile Range (IQR). IQR is a widely used technique for determining consensus and is frequently used in assessing expert opinion (von der Gracht 2012). IQR is a measure of variability based on the distribution of data settled into quartiles. It divides the data into four equal parts, and the dividing values are called the first quartile (Q1), second (Q2), and third (Q3); IQR is equal to Q3 minus Q1. According to von der Gracht (2012), factors/elements with an IQR score equal to one or less (\leq 1) should remain while eliminating the factors/elements with an IQR score greater than one (>1). Figure 2 shows the methodology flow used in this study.

6. Results

The presentation of the results is divided into two parts: validity of game elements and analysis of expert's feedback.

6.1. Game element validity

The overall findings of I-CVI were considered appropriate. Items with I-CVI scores greater than 0.79 were classified as appropriate; revision was needed for items with scores between 0.70 and 0.79, while items were eliminated if they scored below 0.70 (Zamanzadeh et al., 2015). The S-CVI was calculated using the Average CVI (S-CVI/Ave), where the sum of I-CVI obtained was divided by the total number of elements (Zamanzadeh et al., 2015). The S-CVI obtained was divided by the total number of elements is 0.92, as depicted in Table 3. The S-CVI/Ave with a score of 0.9 or higher was interpreted as excellent content validity (Denise and Polit 2006).

To further confirm the content validity, the Kappa statistic was used to calculate the I-CVI's relevancy. This is because even after the chance of agreement is removed, the Kappa statistic can show the proportion of agreement remaining (Wynd et al., 2003). The modified Kappa statistic was used to calculate the I-CVI's relevancy in order to confirm the validity of the contents (Zamanzadeh et al., 2015). The modified Kappa statistic formula, as adapted from Zamanzadeh et al. (2015) is shown below:

$$Kappa = \frac{(I - CVI) - P_c}{(1 - P_c)}$$

- * Pc (probability of chance agreement) = $\frac{N!}{A!(N-A)!} 0.5^N$
- * N = number of experts
- * A = number of experts who agree on the relevant items

Table 1. Analysis of existing serious games related to climate change

Game	Producer	Туре	Carbon Cycle Element	Awareness of Climate Change
Block'Hood	Plethora Project, 2016	Adventure	None Carbon ★ Plants ♂ Human activity ♂ Natural activity ★	Effectiveness of the game was not reported, but received positive ratings in terms of gameplay by gamers https://store .steampowered.com/app/416210/Blockhood/
ECO	Strange Loop Games, 2017	Simulation survival	Yes, but not the main focus Carbon 🗙 Plants 🏈 Human activity 🏈 Natural activity 🏈	Received a low response rate in the survey, and some of the respondents even stated that the game did not increase their environmental knowledge (Fjællingsdal and Klöckner, 2019)
Carbon Runner	Green Ninja, 2018	Running game	Yes, but only in the quiz Carbon Plants Human activity Natural activity	Effectiveness of the game in increasing climate change awareness was not reported; the game was designed for kids
Urban Climate Architect	Games4u stainability	Flash game	Carbon X Plants ♂ Human activity ♂ Natural activity X	Does not allow players to gain substantial insights into complex systems, e.g., systemic effects (Gerber et al., 2021)
Carbon Command	Green Ninja, 2018	Action	Yes, but only on the effect of CO2 Carbon Plants Human activity Natural activity	Effectiveness of the game in increasing climate change awareness was not reported; the game is designed for kids
Climate Cards	Hopeless production, 2018	Card game	Carbon 🗙 Plants 🗙 Human activity 🏈 Natural activity 🗙	Gained only slight engagement, as only 10% of the participants reportedly engaged with the science pack (Foltz et al., 2019)
On Thin Ice	Karn Bianco, 2018	Board game	Yes, but only on the effects of CO ₂ Carbon Plants Human activity Natural activity	Gained only slight engagement, as only 10% of participants reported engaging with the science pack (Foltz et al., 2019)
Rise of Industry	Kasedo Games, 2018	Tycoon	Carbon 🗙 Plants 🕢 Human activity 🟈 Natural activity 🗙	Effectiveness of the game in increasing climate change awareness was not reported. The climate change mechanism is mostly a secondary mechanic that does not affect the gameplay at large.
Oxygen not Included	Klei Entertainment, 2017	Simulation survival	Carbon 🗙 Plants 🗙 Human activity 🗙 Natural activity 🗙	Effectiveness of the game in increasing climate change awareness was not reported. The relationship between gas cycles and temperature is shown in in-game mechanics at a small scale. Does not show the effects of a global climate change.
SimCity 4 by Maxis	Electronic Arts, 2003	Simulation	Carbon X Plants ♂ Human activity ♂ Natural activity X	Only deals with pollution as part of the game storyline and mechanics, and it is not a climate change game

Table 4 shows the summary of Kappa calculations. Elements were considered excellent if the Kappa value is greater than 0.74, good if the value is between 0.60 to 0.74, and fair if it is between 0.40 and 0.59 (Rodrigues et al., 2017). The findings interpreted elements as excellent as the values are greater than 0.74 with Kappa values of a maximum 1 and the lowest with 0.85.

6.2. Expert's feedback

The game elements and their respective IQR values is shown in Table 5. The results show that the IQR of the 13 proposed elements follows the defined value, which is less than and equal to one, thus making it significantly important.

All comments from the experts were examined accordingly. The overall findings indicate that the experts agreed with the design of all game elements and CC content. Nevertheless, these elements were further reviewed based on the experts' comments. A comparison of the game elements from Part 1 and Part 2 of the methodology is shown in Table 6.

7. Discussion

All three CC experts agreed with all the CC game elements. One of the experts emphasised using the right CC terminologies in the game to ensure that the players understand the main issues. This feedback aligns with the research objective to better educate people (players) to understand CC issues, especially the carbon cycle.

Table 2. CC game design elements

Game element	Reference	CC Game description	Validation method
Goal	Goal setting— the first step in design, crucial to game success, it creates the framework from which environment design, rules, dynamics, rewards, and all other components are derived. Therefore, the main goal and target behaviour must be clearly identified before constructing the game (Alexiou and Schippers 2018).	A clear goal must be set in the CC game, to understand the gameplay and win the game easily. The designed goal of the CC game is to save the world from destruction/explosion (CC)	Theoretical validation in order to validate the conceptual framework
Narrative content	The game narrative is a key strategy to achieve engagement; some argue that many CC games have failed because they did not create a fantasy that could be meaningful to the player (Ouariachi et al., 2019).	The narrative content is focused on 3 main elements: carbon, the atmosphere, and the earth—the relationship between gas type, pressure, humidity, and temperature on an immensely complex scale. The players need to balance the amount of carbon produced that cycle around the atmosphere and the earth to control temperature. Human activities produce huge amounts of carbon dioxide. The players need to understand which activities have more impact on CC over others, i.e., identify priorities (what to solve first)	Validate the elements through group discussion with experts
Rules	The core objective is to allow the gamer to enact the rules and thereby achieve brand goals (e.g. create awareness about the protection of the planet's last rainforest frontier (Sreejesh et al. 2018).	The rule of the CC game is to keep the amount of carbon dioxide produced by human activities at a minimum. At the same time, players need to find ways to increase oxygen to balance CO_2 .	The research studied the relation of rules as a game changer. They used an online survey that involved 200 participants
Scope	Many CC games focus on climate protection, with a major focus on international consultation and local technology for greenhouse gas reduction, but few games consider CC elements (Reckien and Eisenack 2015).	Applying the whole carbon cycle as the main context of the game relates to gas type, pressure, humidity, and temperature on an immensely complex scale without neglecting other elements in the carbon cycle, such as respiration and decomposition.	Review and evaluate existing board games for climate change and concluded that the inclusion of the carbon cycle in the game scope is very much needed.
Genre	Climate Card: Simulation, Strategy, Card Block'hood: City Building Simulator Carbon Runner: Action-platformer game Urban Climate Architect: Process Simulation On Thin Ice: Educational, Action, and Arcade FarmVille: Process Simulation playing in a real-life complex situation, players learn how wrong decisions would lead to problems like environmental degradation (Janakiraman et al., 2020; Isa et al. (2019))	The best genre for CC games is simulation, as this genre allows for a real-life gaming experience and could improve understanding of the carbon cycle as much as CC.	Isa et al. (2019) validated the game elements through expert validation on low fidelity prototype
Aesthetic	Aesthetic value and quality of the design implementations in the game design can affect the players' psychological needs and satisfaction (Sailer et al., 2017; Isa et al. (2019)).	The design of the game interface should be a mix of fantasy and reality but should still allow the players to enjoy the game and feel anxious at the same time. It should have a balanced menu design—not too crowded. Multiple colours should be used to illustrate the low and high values of carbon dioxide.	Expert validation on low fidelity prototype
Character design	Character design is important in a game design because characters are the ambassadors of the message and idea that the game makers wish to portray. The game character is the representation of ourselves as part of the game, and it usually determines the success of a game (Zufri et al. 2016; Isa et al. (2019))	The players can choose their characters, skins, and weapons (suited for the environment or problem to solve)—can be collected using coins/real money—increases engagement and enjoyment in playing.	The game elements through expert validation on low fidelity prototype
Game Mode	Players found that co-located multiplayer play with a friend more engaging (i.e. more fun, less frustrating, less tedious) than the same (single- player) experience against an artificial opponent (Siu et al. 2017).	Multiplayer—online mode (Social)	Gameplay method to evaluate players' feedback towards the game mode.
Game Level Design	Types of third-person perspectives include: Aerial (Top-down): shows the player the game as seen from above—a bird's-eye view. Isometric: the player can look slightly across the landscape at a 30- to 45-degree angle. In an isometric world, the player can create many different angles of objects, and then place those objects on the screen. This allows the player to create reusable objects rather than having to render them in real-time. This perspective also makes the player feel closer and more involved with events than a top-down or aerial view (Novak 2012).	Third-person's perspective: Isometric perspective	None (from a theoretical aspect)
Quiz	Carbon Runner helps teach kids about CC and how important it is to implement sustainable practices to better the earth. It does not focus on the carbon cycle process, but it teaches the players by giving a	The quiz can be part of the bonus level in the CC game that covers information on CC issues such that when the player answers the questions correctly,	Validate their finding through experiment (game playing)

Table 2 (continued)

	u)		
Game element	Reference	CC Game description	Validation method
	quiz when they hit the wrong element for the environment. Carbon Runner was developed by Pew Pew studios (Green Ninja, 2018)A quiz game can be a tool to boost reflection, which is considered an important bridge between learning and knowledge (Videnovik et al., 2018).	the player will be rewarded with an increase in Oxygen Level.	
Reward	The reward mechanism is a crucial part of game design that promotes the desired behaviour or attitude in serious games that can directly affect the game experience (Sekhavat 2019) Carbon Runner and Carbon Command reward players with carbon cash if they answer the quiz correctly. The carbon cash can be used to upgrade items in the game. [https://greenninja.org/ resources]	To motivate players to keep playing while learning Oxygen Level, Experience Point (XP), CO ₂ Level, achievement, profile	Validate the outcome of the studies through a survey
Challenge	A challenge is a central constituent of the gameplay in most digital games and is widely believed to play a crucial role in making games enjoyable. The challenge is an experience that many players seek in digital games, and it is central to the overall enjoyment of many games (Denisova et al., 2020).	The challenge for CC games is designed in multiple ways in terms of a time limit, natural hazard, villain, and simultaneous tasks to complete.	Validated through questionnaire
Rank	Ranking is the cornerstone of LoL's competitive gaming practices, which shapes the ways players distinguish and narrate their gaming experiences, thus engendering a culture of collaboration and competition through distinction (Kou et al. 2016).	The level rises when XP increases to a certain benchmark. Players can upgrade items once they level up.	Validate the ranking through interview with 16 experts

In terms of game design perspective, the four experts on game design provided more suggestions in the comment box and rated most of the elements more with a score greater than 3. One of the experts on game design suggested changing the game genre to a strategy game (the current genre is a simulation). The expert is not against classifying the game as a simulation, but he opined that it is more suitable for a CC game to be designed as a strategy game. Depending on the game creator and the game market, it is common for games to fit into more than one genre. For example, a highly popular multiplayer game, PlayerUnknown's Battlegrounds (PUBG), is a battle genre that has been acknowledged as one of the e-sport games registered in the Malaysian E-Sports Tournament. Many players strategize to win, so some players believe that the game belongs to the strategy genre. The simulation genre attempts to copy various activities from real life in the form of a game for learning or training. The strategy genre includes games that require decision-making skills, which are significant in determining outcomes (Janakiraman et al., 2020). Both genres can be combined to create a more suitable genre for CC games.

Another issue highlighted by one of the experts on the game design was the quiz element. The expert considered quizzes as only suitable for e-learning materials rather than for games and rated 1 for that element. The other six experts rated the quiz element a 4 or 5, which caused the average value of the quiz element to go below 4 points (3.86). Nevertheless, another expert on game design criticised the suitability of the term "quiz" in a game. The quiz element is important to reflect the players' understanding. Quizzes are a common way to test the players' skills and knowledge. However, in a commercial game, players' understanding can also be tested by giving them small tasks in between the game to reward them with some points or coins, while at the same time testing their understanding of CC or the carbon cycle. The quiz element

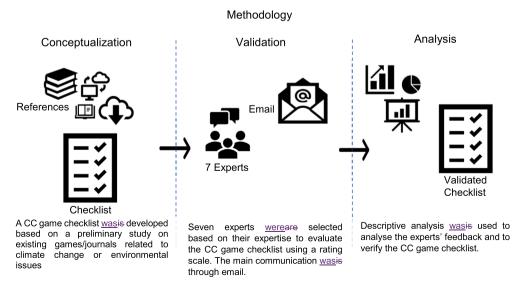


Figure 2. Research methodology.

Table 3. S-CVI for CC game element.

Game Element	E1	E2	E3	E4	E5	E6	E7	Experts in Agreement	I-CVI	Interpretation
Goal	4	5	4	5	5	5	4	7	1	Appropriate
Narrative Content	5	5	4	5	5	4	4	7	1	Appropriate
Rules	5	5	4	5	5	4	4	7	1	Appropriate
Game Mode	5	5	4	4	5	5	4	7	1	Appropriate
Rank/Level	4	5	4	5	5	5	4	7	1	Appropriate
Reward	5	5	4	5	4	4	4	7	1	Appropriate
Scope	5	5	4	3	5	4	4	6	0.86	Appropriate
Player Character	5	5	4	5	2	5	4	6	0.86	Appropriate
Challenge	5	5	4	4	5	3	4	6	0.86	Appropriate
Type/Genre	4	5	4	4	3	5	4	6	0.86	Appropriate
Aesthetic	5	5	4	4	3	4	4	6	0.86	Appropriate
Level Design	5	5	4	5	4	2	4	6	0.86	Appropriate
Quiz	4	5	4	4	5	1	4	6	0.86	Appropriate
								S-CVI/Ave	0.92	Excellent

Table 4. Kappa values for CC game elements.

Game Element	Pc	Kappa (k)	Interpretation
Goal	0.0078	1	Excellent
Narrative Content	0.0078	1	Excellent
Rules	0.0078	1	Excellent
Game Mode	0.0078	1	Excellent
Rank/Level	0.0078	1	Excellent
Reward	0.0078	1	Excellent
Scope	0.0546	0.85	Excellent
Player Character	0.0546	0.85	Excellent
Challenge	0.0546	0.85	Excellent
Type/Genre	0.0546	0.85	Excellent
Aesthetic	0.0546	0.85	Excellent
Level Design	0.0546	0.85	Excellent
Quiz	0.0546	0.85	Excellent

Table 5. Game element verification by panel experts.

Game Element	E1	E2	E3	E4	E5	E6	E7	Q1	Q3	IQR
Goal	4	5	4	5	5	5	4	4	5	1
Narrative Content	5	5	4	5	5	4	4	4	5	1
Rules	5	5	4	5	5	4	4	4	5	1
Game Mode	5	5	4	4	5	5	4	4	5	1
Rank/Level	4	5	4	5	5	5	4	4	5	1
Reward	5	5	4	5	4	4	4	4	5	1
Scope	5	5	4	3	5	4	4	4	5	1
Player Character	5	5	4	5	2	5	4	4	5	1
Challenge	5	5	4	4	5	3	4	4	5	1
Type/Genre	4	5	4	4	3	5	4	4	4.5	0.5
Aesthetic	5	5	4	4	3	4	4	4	4.5	0.5
Level Design	5	5	4	5	4	2	4	4	5	1
Quiz	4	5	4	4	5	1	4	4	4.5	0.5

was combined with the reward element, and the name was changed to task and reward but still carried the objective of testing the players' knowledge on CC.

One of the experts rated the players' character element a 2, while others rated the element 4 or 5. The players' character element allow the players to change their skin and weapons. However, according to the expert, weapons are not needed in CC games. Nevertheless, in this game, a weapon could include a machine or technology, a reference book, a Table 6. Expert comments.

No.	Conceptualisation	Recommendation
1	Goal	Retain
2	Narrative Content	Retain
3	Rules	Retain
4	Game Mode	Update description
5	Rank/Level	Update description
6	Reward	Update description and combine with Quiz
7	Scope	Retain
8	Player Character	Update description
9	Challenge	Update description
10	Type/Genre	Update type to multiple genre
11	Aesthetic	Update description
12	Level Design	Update description
13	Quiz	Combine with Reward

certificate of authority, or even a real weapon to fight villains who commit destruction. Thus, the suggestion to remove weapons in the players' character element was disregarded.

One of the experts on game design emphasised using clear descriptions for all game elements, especially for the challenge and gamelevel elements. The expert suggested clearly describing the elements to avoid over planning, which may cause inflexibility. Another expert on game design drew attention to the categories of the elements in the checklist. The expert suggested categorising the elements into five categories, namely mechanics, aesthetics, pedagogy, story, and technology. Nevertheless, the category of the game element and the game term is interchangeable based on the author or researcher. More importantly, the researcher or game designer can describe the category clearly so that other researchers or game designers can comprehend and follow the tips to design the game elements in a CC game.

The final game elements after the expert validation are as shown in Table 7.

8. Conclusion and future works

CC has been one of the biggest issues affecting the entire world in recent years. Many efforts have been made to address this issue by introducing new technological innovations or creating operative awareness to lessen the effects of CC. In essence, this research focuses on creating awareness of the carbon cycle that directly influences CC, especially among the young generation. Since the young generation is very much into playing games, this medium was selected to convey

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Table 7. Game design elements in serious game for climate change.

No.	Game element	CC Game description
1	Goal	A clear goal must be set in the CC game so players can easily understand how to win the game. The goal of the CC game is to save the world from destruction (CC).
2	Narrative content	The narrative content is focused on 3 main elements: carbon, the atmosphere, and the earth—the relationship between gas type, pressure, humidity, and temperature on an immensely complex scale. The players need to balance the amount of carbon produced that cycle around the atmosphere and the earth to control overall temperature. Human activities produce huge amounts of carbon dioxide. The players need to understand which activities have more impact on CC over others, i.e., identify priorities (what to solve first). Given a situation in which the world is polluted, the player acts as the mayor of the town whose mission is to control the rate of pollution in town. The mayor controls carbon intake by making decisions in rebuilding the town. In this world, players play with O_2 cash as the reward, where the more O_2 one can gain, the healthier the town will be. However, players need to be careful with the CO_2 intake in the town. Once the mayor succeeds in achieving a certain benchmark on the O_2 and CO_2 intake in the town, the mayor can save the next town (level).
3	Rules	The rule of the CC game is to keep the amount of carbon dioxide produced by human activities at the minimum level. At the same time, the players need to find ways to increase the amount of oxygen to balance the amount of CO_2
4	Game Mode	Multiplayer: Online Mode (Social)
5	Rank/Level	The level rises when XP increases to a certain benchmark. Players can upgrade items once they level up.
6	Task and Reward	The quiz can be included in a bonus level in the CC game that covers information on CC issues. When players solve small tasks, the players will be given the Oxygen Level as a reward. This reward can motivate players to keep playing while learning—Oxygen Level, XP, CO ₂ Level, achievement, profile.
7	Scope	To apply the whole carbon cycle to the main context of the game without neglecting other elements in the carbon cycle, such as respiration and decomposition.
8	Character Design	The players can choose their characters, skin, and weapon (suited to the environment or problem to solve)—can be collected using coins/real money, increasing engagement and enjoyment in playing.
9	Challenge	CC games' challenge is designed in multiple ways in terms of a time limit, natural hazards, villains, and simultaneous tasks to complete.
10	Type/Genre	The strategy and simulation genre allows for a real-life experience while playing. It can also improve the players' understanding of the carbon cycle concept as much as CC's.
11	Aesthetic	The game interface should appear to be a mix of realistic and imaginary elements but must still let the players enjoy and feel anxious at the same time. It should have a balanced design for the menu and should not be too crowded. It should also use multiple colours to illustrate the low and high values of carbon dioxide.
12	Level Design	The third-person perspective in the CC game will allow the players to view the characters that they control as the characters are visible on the screen. The isometric view is one of the third-person's perspectives, where players can view a 30-to-45-degree angle on the game level, which will make it easier for them to interact with the objects in the game.

awareness. However, the limited references on CC games have made creating awareness via games less feasible. Thus, this research aim is to identify and validate game design elements in serious game for climate change During the preliminary study at the beginning of this research, various information regarding the CC game was gathered. This research took about ten weeks, with multiple filtering cycles, to finally put all relevant information on a checklist. The checklist consists of 13 game elements: Goal, Narrative Content, Rules, Scope, Type/Genre, Aesthetic, Player's Character, Game Mode, Level Design, Quiz, Reward, Challenge, and Rank/Level. Each game element is designed to relate to the content, which is the carbon cycle and CC. Therefore, two areas of expertise, CC and game design, were associated with the design of the checklist. To validate the checklist content, experts from both fields were invited. Hence, seven experts were appointed to verify the game elements. This process took around six weeks. The feedback from the experts was analysed, and some changes were made. In total, 12 game elements were finalised at the end of the process, namely Goal, Narrative Content, Rules, Scope, Type/Genre, Aesthetic, Player's Character, Game Mode, Level Design, Quiz and Reward, Challenge, and Rank/Level.

The experts' validation process is a crucial step in verifying the game elements. Thus, it is important to ensure that the appointed experts have good experience and knowledge in the concerned area, as there is no doubt that their feedback can give weight to the final outcome. It is even better if the identified CC game elements can be tested by developing a game prototype. The future work will be forming the paper prototype, a low-fidelity prototype, with the implementation of all the 12 elements discussed in this paper. Then, the same experts can evaluate the game prototype, and this process can be considered as another verification cycle. Hence, validation via game prototype is one of the plans for future research.

All reviews by the experts are self-reviewed without face-to-face explanation because a certain standard procedure had to be applied due to the COVID-19 pandemic. However, each expert was briefed on his/her respective task via online discussion.

Declarations

Author contribution statement

Nor Azan Mat Zin, Norizan Mat Diah: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Ratna Zuarni Ramli, Nurlieda Ellyanna Munirrah Razali: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Hazura Mohamed, Fadhilah Rosdi: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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