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Serious Games for Climate Change Engagement: A User-Centered Design Approach

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Abstract. Climate change is a critical global challenge that requires innovative educational tools to promote awareness and engagement. This paper examines the potential of serious games as an interactive media tool for climate change engagement, offering a framework and recommendations for future serious game design in this context. To validate the framework, we developed a serious game concept and prototype *EcoLand* using the proposed recommendations. *EcoLand* was created utilizing a user-centered design approach, which integrated gamification techniques and user experience principles to enhance engagement and educational impact. The research process follows the design science research process and includes literature review, game review, conceptual framework development, prototype creation, and user testing through structured tasks and a questionnaire. Our findings suggest that user-centered serious games can effectively simulate real-world climate challenges, enhance experiential learning, and support sustainable thinking and action. This study highlights the value of involving users in the design process to improve both user engagement and communication effectiveness. This paper contributes with both a theoretical design framework and recommendations for designing serious games that make climate change more relatable and actionable for diverse users, as well as empirical findings.

Keywords: Climate change, Serious games, User-Centered Design, User experience, Gamification, Game design, Sustainability

1 Introduction

Climate change is a global socio-environmental challenge [1] that requires innovative communication strategies to promote awareness, engagement, and sustainable behavior. Despite the importance of addressing this issue, significant gaps in knowledge, awareness, and motivation to act persist, leaving many unaware of the causes and consequences of hazardous behaviors and the need for change [2,3] as well as the solutions available and the urgency of the situation [4,5]. Traditional educational and communication methods have struggled to effectively engage audiences and inspire meaningful behavioral change regarding climate change [6]. The complexity of the climate change issue, the cognitive and psychological aspects of information processing, and the politicization of the topic make the communication task difficult or unsuccessful [7].

Serious games that entertain while focusing on a specific goal [8] offer a promising alternative. A literature review of several game-based interventions indicated that, when designed using a mix of user-centered design (UCD) approach, user experience (UX) principles and game elements, the serious games can facilitate awareness while encouraging reflection, discussion, and informed action [9]. By combining interactive elements, playful and experiential learning [9], they allow players to explore real-world issues through simulated environments, potentially making complex climate topics more understandable and relevant.

This paper presents a conceptual design framework and recommendations for creating effective serious games for climate change engagement, exploring their potential through the design and evaluation of the *EcoLand* prototype game. The design incorporates game design techniques, UCD principles, and UX design to ensure both engagement and educational value. To guide this investigation, this study addresses the following two research questions:

- RQ1: What recommendations for user-centered design of serious games for climate change engagement can be derived from the literature and best game design examples?
- RQ2: When applying these recommendations in game design, what user-centered process is followed, and what are the results in terms of user engagement?

This study provides recommendations for a conceptual framework for serious game design focused on climate change engagement to answer RQ1. It further assesses the feasibility and effectiveness of these recommendations (RQ2) in game design, demonstrating that a UCD approach, grounded in theory and empirical research, can create effective interactive tools for climate communication, providing insights for designers, educators, and researchers.

2 Research Methodology

This study employs a theoretical analysis, game reviews, and design science research (DSR) to answer the RQs. Three primary outcomes result: literature and game review analysis and findings, a conceptual framework (answering RQ1), and a serious game prototype creation and evaluation (answering RQ2). The DSR methodology [10,11], a problem-solving approach in five stages, is suitable when the problem is complex and the solution is an innovative artifact whose development is iterative and generates knowledge [10]. DSR methodology provides a structured yet flexible model to iteratively design, test, and refine the solution, in this case, the serious game design. Table 1 summarizes the application of the DSR methodology [11] in this study.

The study contributes both to the knowledge base of HCI through developing a design framework and recommendations as well as to the empirical HCI through developing a design process, a serious game prototype, as well as analyzing user tasks, questionnaires and empirical findings related to evaluating the prototype. Table 2 highlights the research relevance, rigor and contributions according to the DSR framework [10].

Table 1. DSR methodology used in this study following the Peffers et al. [11] model

DSR Stage	Application in Research
Problem Identification	Recognizing climate change communication and engagement as a critical issue requiring innovative solutions
Objective Definition	Designing a serious game to raise awareness and promote sustainable engagement
Design and Development	Creating the *EcoLand* prototype using the conceptual framework and a user-centered design approach.
Evaluation	Conducting user testing to assess usability, engagement, and educational impact
Communication	Sharing findings and refining the game based on the feedback received to improve learning outcomes and engagement.

Table 2. Mapping the research components on Hevner et al. [10] research framework.

Framework	Rigor and Relevance	Research Contributions
Environment	*Communicate climate change* to people and organizations using interactive, digital media.	People: Target users in age group 16+. Organizations: Society, University, Schools, Media. Technology: Serious games, UX design, Figma.
Knowledge base	*Conduct literature review* on related concepts (climate change communication, climate change engagement, gamification, game design, and user-centered design). *Conduct game reviews* to synthesize best practices. *Analyze and apply* relevant theories, models and frameworks of communication and design. *Use established methodologies in evaluation*: usability and user experience evaluation methods.	Literature synthesis, Empirical game review, Design recommendations, Conceptual framework on serious game design, Design process model, User evaluation tasks, scenarios, questionnaires.
HCI & UX Research	*Build and evaluate a serious game for climate change engagement*	Develop *EcoLand* game prototypes, User testing, and Questionnaires, Empirical findings.

The literature review builds the theoretical foundation of the study by examining key concepts such as climate change communication and engagement, game-based learning, user experience and interaction design, and games, serious games, and gamification design techniques and elements. Game reviews focused on available games addressing climate change or environment topics. Findings from the literature and game reviews were synthesized into a conceptual framework that offers actionable recommendations for designing serious games for climate change engagement. The proposed conceptual design framework was then used to develop the serious game prototype *EcoLand*.

3 Background

In this section, we summarize key concepts, theories and findings from the literature review that constitute the knowledge base of the study.

3.1 Climate Change Education, Communication and Engagement

Environmental education is a vital tool for promoting sustainable behavior and climate action. However, climate education faces challenges such as scientific complexity, public misconception, misinformation, and lack of engagement [12]. Moreover, traditional fact-based teaching often fails to inspire action. Hence, informal education, through communities, media, and social networks, can inform adults about climate issues, fostering involvement and showing that they can make a meaningful impact [13,14].

Effective communication should be two-way, interactive, and emotionally resonant, enabling citizens to connect with the issue and participate in solutions [15]. Climate change communication should be interdisciplinary, incorporating scientific, social, political, and economic perceptions [16]. It should use local, visual, and interactive methods that promote critical thinking and reflection on alternative lifestyles. Solutions should integrate awareness, knowledge, skills, values, and participation opportunities for meaningful communication [17].

Climate change engagement is a multidimensional concept incorporating cognitive, affective, and behavioral responses at individual and collective levels; individuals and groups understand and think critically about the climate issues and environment, they feel concerned about them or have emotional connections to climate and environment, and they act or are motivated to act towards mitigating or adapting to climate change [7, 18]. Information communication technology (ICT) and digital media can simplify access to complex issues through visualization, simulation, and interactivity, encourage dialogue, and support climate action through a four-stage engagement process comprising communication, education, empowerment, and deliberation [15].

3.2 Serious Games, Game-Based Learning, and Gamification

Serious games can emotionally and cognitively engage players, supporting behavior change through playful learning, social interaction, and feedback mechanisms [15,19]. Serious game design relies on game-based learning (GBL) that appeals to users through play, motivational elements and psychological theories [20]. Serious games are intentionally designed to achieve primary goals such as education, competence enhancement, or learning a new skill [8,21] along with playful experiences. Serious games are thus useful in communicating and enhancing the understanding of complex issues like climate change. By simulating real-world scenarios, these games help players to emotionally connect with problems and explore sustainable solutions [22]. These games simplify the complexities of climate change ramifications, making them more visible, tangible, and relatable. Gamification is a process or solution that incorporates the elements of a game such as mechanics and motivational affordances [23,24] to increase engagement and boost behavioral change or motivation. Features such as leaderboards,

rewards, and collaborative goals foster social connections and pressure, form habits, and enhance emotional engagement, encouraging sustainable behaviors [25, 26].

There are several game design frameworks and more specific serious game and gamification design frameworks and guidelines in the literature (see for reviews, [9, 27,28,29]). Each of these available frameworks focuses on different issues such as evaluation aspects, the whole design process, or they are based on different research materials such as industry practices [30], empirical research findings [9], and thus they are valuable but have specific applicability.

3.3 User-Centered Design and Interaction Design

The UCD approach aims to enhance usability in systems by addressing user needs, resulting in improved accessibility, satisfaction, and effectiveness. Utilizing UCD principles, such as user involvement, iterative development, simple design, prototyping, contextual evaluation, and multidisciplinary collaboration in serious game development, ensures that the game remains relevant, engaging, and aligned with user expectations [31]. Interaction design is a broader approach that focuses on creating engaging user experiences, interfaces, and human-computer dialogues by improving usability and emotional satisfaction [32]. When applied to game design, it employs principles such as game flow, motivation, and user feedback to ensure the users remain engaged and experience high levels of satisfaction while interacting with the game. Involving users in game design includes workshops [33] but also online sessions or surveys as well as observing or researching existing systems [34] for eliciting initial requirements, design solutions, as well as user evaluations. Combining interaction design, UCD, and serious game design will result in immersive and effective learning experiences [9].

3.4 Empirical Game Review

To answer RQ1, alongside the literature review summarized above, we also reviewed ten environmental games selected systematically based on a protocol defined for this purpose. The games had to be freely available in digital format, designed explicitly to address climate change or environmental sustainability (e.g., global warming, recycling, energy conservation, sustainable practices), provide educational content alongside entertainment, and be available in English language.

The review followed an environmental game design framework [35], which includes four categories of analysis and design: Player actions, Learning and knowledge dissemination, Motivation and engagement, and Social interaction. Each game was evaluated against these four categories and corresponding criteria, such as fun and meaningfulness for Motivation and engagement, achievable and challenging for Player actions, experiential learning and simulation for Learning and knowledge dissemination, and presence of social elements for Social influence category.

The games reviewed provided ideas for the practical implementation of the game elements according to [35]. For example, successful games incorporated decision-making simulations, experiential learning, and interactive quizzes to enhance the understanding of climate change issues. They used clear feedback mechanisms and rewards

to motivate continued engagement. Among the flaws observed, some games lack consistent or comprehensive narratives and engaging gameplay, which reduces long-term engagement and educational impact.

Similarly, existing literature reviews on similar games highlighted limitations such as lack of long-term evaluations of these games and how specific gameplay mechanics, such as narrative approach, multiplayer features, feedback, and rewards, impact the learning outcomes [9,36]. Factors like credibility, achievability, meaningfulness, and social aspects were not thoroughly mapped to impact on users [9].

The game review also indicated that design flaws in terms of lacking in narrative or social features, integrating empathy, and challenging and engaging gameplay can reduce user engagement. Hence, investigating ways to integrate more collaborative features together with optimizing UX is essential for achieving better engagement.

4 Design Recommendations and Conceptual Framework for Climate Change Engagement Serious Games

Based on the literature and game reviews, a comprehensive list of ten recommendations (R1-R10) for the development of climate change serious games is presented. These form the basis of the proposed conceptual framework for serious game design, shown in Table 3, which consists of four components: *Context of use, Gameful and learning experiences, Engagement goals, and Game design principles*.

R1. **Narrative and engagement**: Create engaging, story-driven scenarios that immerse players in climate decision-making. Use narratives to illustrate the impact of actions, promote empathy through role-playing, and add timed challenges to instill urgency for climate action.

R2. **Scientific accuracy and relevance to real-world facts**: Integrate real-world climate data and collaborate with scientists for credibility. Using updated local scenarios enhances learning and addresses misconceptions through gameplay.

R3. **Social interaction and community engagement**: Use collaborative or competitive modes for peer learning and engagement. Incorporate forums, group challenges, and community dialogues to promote collaboration. Involve players in real-world climate research through activities like data collection and analysis.

R4. **Learning and behavioral change**: Incorporate features like goals, challenges, rewards, and simulations to promote experiential learning and encourage sustainable behaviors. Include adjustable difficulty levels for varied engagement and provide explanations on the real-world consequences of decisions made in the game.

R5. **Long-term engagement and evolution**: Incorporate game elements like leaderboards and ongoing challenges to engage players. Add mini-games for variety and regularly update climate change content with the latest science. Reward long-term participation to encourage learning and behavior change.

R6. **User-centered design**: Design intuitive navigation and accessible visuals for a better user experience. Offer gameplay customization with options for avatars,

narrators, and locations. Ensure multilingual support and culturally sensitive content to engage a diverse audience with varying interests and needs.

R7. **Iterative design and feedback**: Continuously assess and refine the game based on feedback from users, experts, and stakeholders. Collaborate with various stakeholders, including educators, scientists, and psychologists, for a balanced design.

R8. **Ethical design**: Avoid misinformation through oversimplifying or overcomplicating the situations. Fairly represent climate science and communities.

R9. **Platforms and technologies**: Develop mobile-friendly to maximize accessibility. Use simulations to allow exploration of long-term impacts.

R10. **Integration with existing systems or programs**: Develop curriculum-aligned educational games and partner with environmental organizations to boost credibility and impact. Use tools to track learning outcomes and engagement for evaluation.

Table 3. Conceptual framework for climate engagement serious game design

Gameful and learning experience	Engagement goals	Game design principles	Context of use
Narrative and engagement (R1) Scientific accuracy and relevance to real-world facts (R2) Social interaction and community engagement (R3)	Learning and behavioral change (R4) Long-term engagement and evolution (R5)	User-centered design (R6) Iterative design and feedback (R7) Ethical design (R8)	Platforms and technologies (R9) Integration with existing systems or programs (R10)

5 *EcoLand* Game Design

To answer RQ2, a serious game prototype was designed by incorporating the conceptual framework and recommendations derived from literature and game reviews. Designed as a mobile game, *EcoLand* aims to engage players with climate change through a playful, emotional experience that educates, simulates real-world scenarios and encourages sustainable actions (R1-R5).

The design followed a UCD approach and process (R6-R10) shown in Fig. 1, that was also created for this study based on existing frameworks, models, and concepts related to software development and game design [34,37-44]. In short, the game design life cycle (GDLC) process model covers all the stages of developing a serious game while promoting iterative development and improvement by integrating feedback from users, stakeholders, and testers at every stage. It addresses the requirements (R1-R10) in the conceptual framework (Table 3) by defining the context, ideating content and mechanics, and enhancing emotional, cognitive, and behavioral engagement with climate change over time.

The core concept of *EcoLand* is to promote individual engagement with climate change through a structured game flow based on the four-stage engagement model [15]: *communication, education through experiential learning, empowerment,* and *deliberation or agency*. The game story is placed in the fictional state of Climore, where players

act as government advisors working to transform the area into a sustainable society, navigating the balance of ecological, financial, and social goals through interactions and decision-making. The following section details the game flows, target audience, and how recommendations were translated into game features.

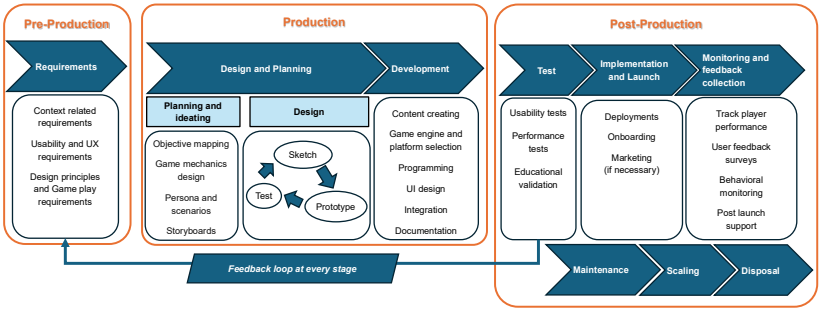

Fig. 1. Game design life cycle (GDLC) for serious games created and applied in this study

5.1 Game Flows and Game Loops

Game flow is key to player engagement and enjoyment in video games. It refers to a state of immersion where players are fully absorbed in gameplay. Elements like an immersive storyline, clear goals, rewards, and emotional connection to characters maintain the gameplay [45]. *EcoLand* features three main game flows: the **introduction flow** (Fig. 2) for onboarding, story narration and tutorials; the **core game flow** (Fig. 3) for resource management and challenges; and the **endgame flow** (Fig. 4), which summarizes player's choices and concludes the narrative with a cinematic ending.

Fig. 2. The introduction game flow (Tutorial and setup)

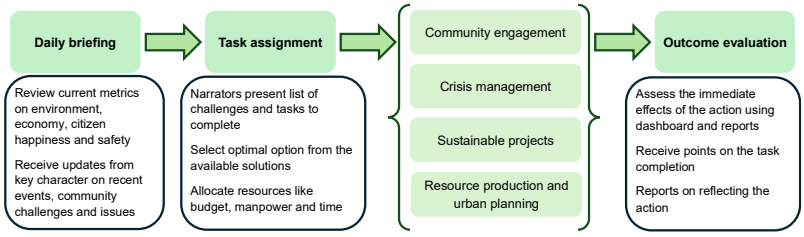

Fig. 3. The core game flow (Decision-making and management)

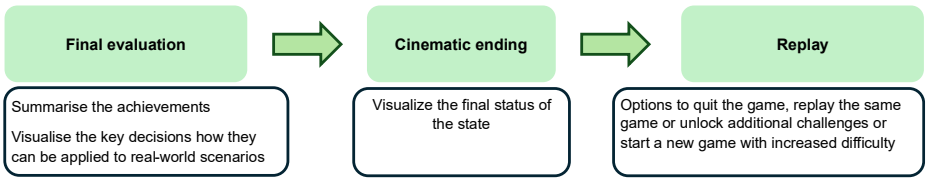

Fig. 4. The endgame flow (Victory or failure)

To maintain the engagement and game flow, EcoLand uses a layered game loop structure [46] that ensures both short-term and long-term commitment. The primary loop includes daily tasks such as decision making, resource allocation, and project execution. The secondary loop introduces dynamic challenges like minigames and disaster events to diversify the gameplay. The tertiary loop supports long-term engagement through fictional media updates, policy reflections, and social sharing features.

5.2 Target Audience

The game targets users aged 16 and above, regardless of their climate change knowledge. Creating user personas representing diverse attitudes and motivations (e.g., high school visionary, gamer, traditionalist, reluctant professional, climate activist) guided the design and understanding of the user interactions [34]. A user scenario and a use case were created to enhance the understanding of user interaction with the game.

5.3 Features of *EcoLand*

Features of the game (Table 4) were chosen and designed based on the recommendations proposed in section 4 and alignment with the goals of the game and user needs as defined by applying the design process in Fig. 1. Key elements like role-playing with important characters, real-world simulations, customizable difficulty levels, and motivational UX elements (rewards and feedback) are employed to encourage meaningful engagement. In *EcoLand*, players face challenges that require balancing environmental, economic, social, and security factors in the state. To enhance engagement, the game includes a 'Minigame Bar' for time-limited minigames that reward players with *eco-points* for use in the main game. Players can also view real-world news or climate research before each minigame, connecting gameplay with current events. Examples include garbage sorting, ocean cleanup, and climate change quizzes.

5.4 Design Prototypes

During the initial design stage, paper prototypes were created, followed by digital prototypes (Fig. 5) in Figma (www.figma.com). This iterative process refined the user interface, game flow, and mechanics without fully implementing the software. A limited number of user flows were designed, using images from www.freepik.com under the Free License and Canva Dream Lab (www.canva.com/dream-lab) images under Canva's Content License Agreement.

Table 4. Features used in *EcoLand* according to the proposed list of recommendations.

Recommendation	Features Used in *EcoLand*
1. Narrative and engagement	Starts with a narrative on the climate crisis and the current situation of the state Role-playing with supporting characters like the governor and the environmentalist Include time-based challenges and minigames
2. Scientific accuracy and relevance to real-world facts	Develop with generally correct real climate data and real news Game challenges simulate urban planning, sustainable actions, and real-world scenarios where users can learn by experimenting Challenges present choices that help correct the misassumptions
3. Social interaction and community engagement	Players can add friends, chat, support each other, and share achievements on social media The game includes chat about news, research, and collaborative features Citizen science features are not included in this prototype
4. Learning and behavioral change	Includes motivational features like rewards, reminders, suggestions, praise, trustworthiness, credibility, social support Leveling up increases difficulty and complexity Players visually experience the consequences of their decisions
5. Long-term engagement and evolution	Includes minigames, evolving tasks, and narratives to feel connected Timely news and research data in minigames Rewards like Eco-points, daily login rewards, and achievements to encourage engagement
6. User-centered design	Simple UI focused on enhanced user experience Players can select the difficulty level Accessibility is not addressed fully in the prototype. Development can include multilingual access and future challenges, and news with culturally relevant content
7. Iterative design and feedback	User evaluation to assess effectiveness and recommendations for future refinement Prototype only includes scientific, environmental, and educational general information. Future development should be done with multi multidisciplinary team
8. Ethical design	Real-world based, avoids oversimplification
9. Platforms and technologies	Designed as a mobile game Simulates long-term impacts of human actions and decisions through challenges
10. Integration with existing systems or programs	Not included in this prototype, but to be taken into account in the next iteration. The current design was using a scenario and use case where a high school student starts playing the game to learn more about the climate and the environmental behavior.

Fig. 5. Some dialogs in *EcoLand*

6 User Evaluation and Analysis

To further answer RQ2, a user evaluation of *EcoLand* was conducted online to assess user engagement and its effectiveness in promoting climate change awareness. The focus was to identify usability issues, design flaws, and enhance user experience through feedback [47,48]. The evaluation included quantitative analyses and qualitative feedback on clarity, functionality, and conceptual effectiveness of the design (player interest, expectations, engagement) rather than gameplay efficiency.

6.1 Test Structure

The test used an online questionnaire divided into three parts. First, a **pre-test** collected demographic data, including age and familiarity with environmental games. Next, participants completed six tasks, each followed by an **in-test questionnaire**. Finally, a **post-test** gathered feedback on overall experience, engagement, usability, and learning.

6.2 Test Participants

An online test invitation was sent to around 100 people aged 18 and older, with 29 responding. Most participants were aged 25-34 (19), followed by 35-44 (7) and 18-24 (3). The gender distribution was 19 females and 10 males, with participants showing varying familiarity with games promoting environmental awareness (see Fig. 6).

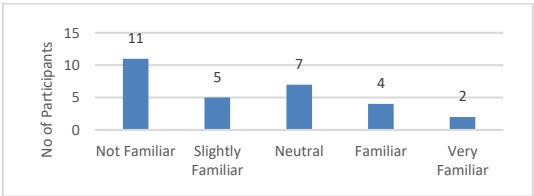

Fig. 6. Participants' familiarity with environmental or climate change awareness games.

6.3 Quantitative Analysis

The quantitative analysis of the evaluation test data focused on three areas:

- Usability assessment and mapping the answers to the system usability scale (SUS).
- User experience of the game.
- Effectiveness and engagement of the game prototype.

Usability Assessment. SUS is a tool that assesses system usability with ten questions focused on user satisfaction and various usability aspects like effectiveness and ease of learning measured on a 5-point Likert scale (1 Strongly Disagree - 5 Strongly Agree) [49]. In this study, questions were mainly based on [22] and adapted to benchmark the game usability. We mapped the questions and the corresponding scales to the SUS scale and obtained an overall estimation of SUS (see Table 5 including the mean and standard deviation SD statistics for the transformed scales).

SUS scores for each participant's responses were then calculated using the SUS score calculator [50], obtaining scores in the range 1-100 and categorized into grades A - F (where A signifies the best imaginable usability, and F poor usability). Most participants (59%) rated usability as Grade A+, and 10% as Grade A, indicating the best imaginable usability. Across the sample, the average overall SUS score of 83 highlights exceptional usability (Grade A or best imaginable). Six participants (20%) rated the overall usability as Grade C (good) with scores between 65 and 72.5. Two users indicated poor (42.5) or okay (52.5) usability, finding issues with loaded designs, too small font size, too much text, as well as having problems with profile creation.

Table 5. Mapping of user test questions to SUS standard questions [49].

SUS standard question, Likert scale 1-5	Score Type	Mean	SD
1. I think that I would like to use this system frequently.	Direct	4.27	0.93
2. I found the system unnecessarily complex.	*Reverse*	1.51	0.61
3. I thought the system was easy to use.	Direct	4.05	0.91
4. I think that I would need technical support to use this system.	*Reverse*	1.18	1.22
5. I found the functions in this system well-integrated.	Direct	3.82	1.00
6. I thought there was too much inconsistency in the system.	*Reverse*	1.25	1.38
7. I would imagine that most people would learn to use this system very quickly.	Direct	4.39	0.67
8. I found the system cumbersome to use.	*Reverse*	1.45	0.56
9. I felt very confident using the system.	Direct	4.32	0.93
10. I needed to learn a lot before I could use the system.	*Reverse*	1.30	0.93

User Experience. In this analysis, UX of the game prototype was evaluated based on ten UX features on a scale 1(low UX) -7 (high UX), mapped to six categories:

attractiveness, efficiency, perspicuity, dependability, stimulation, and **novelty** [51]. Table 6 presents the UX evaluation categories and features, and the evaluation results.

Table 6. UX categories and features evaluated, scale 1 low, 7 high

UX Category	Description	UX features in the test	Mean	SD
Attractiveness	The overall impression of the product in terms of appeal and enjoyability.	Unattractive/Attractive	6.14	0.97
Perspicuity	Easy to learn and understand the system without unnecessary effort.	Hard/Easy to learn	6.21	0.89
Efficiency	Product is engaging, exciting and enjoyable to use, enhancing usability.	Impractical/Practical	6.28	0.98
Dependability	Users feel confident and predict the system's behavior.	Not friendly/User friendly	6.24	1.01
Stimulation	Product is exciting and interesting to use, enhancing motivation.	Not interesting/Interesting Demotivating/Motivating Not engaging/Engaging	6.09	1.07
Novelty	Creativity and innovative nature of a system.	Useless/Useful Dull/Creative Inferior/Valuable	6.31	0.99

User responses indicate that all six UX categories for the *EcoLand* prototype, attractiveness, efficiency, perspicuity, dependability, stimulation, and novelty, averaged above 6 out of 7, reflecting a strong and consistent UX with low standard deviations.

Effectiveness of Gamification Features. Descriptive statistics were analyzed to assess the effectiveness of gamification features, including narrative, challenge intuitiveness, enjoyment of minigames, inclusion of news articles, and social media sharing (Table 7). Results show relatively high average scores across the sample ranging from 3.45 to 4.59 out of 5, with consistent user feedback (relatively low standard deviation).

Table 7. Statistical summary on the effectiveness of the gamification features (1 low, 5 high)

Feature	Mean	SD
Engagement in the **narrative** introduction	4.14	1.04
Intuitiveness of **challenges**	3.97	0.999
Enjoyability in the **minigame** concept	4.59	0.89
Engagement in the **minigame** concept	4.45	0.97
Interest in **incorporating news and research articles** in the game	3.45	1.40
Opinion on including a feature to **share progress** on social media	4.21	0.92

Climate Change Engagement. The user test evaluated the **player preferences** for the type of engagement (informative, educative, empowering, and agentic [15]) on a 4-point scale (with 1 being the most preferred). The analysis indicated a preference for fact-based, informative (mean rank 1.97) and interactive, educative approach (2.41) in a climate-related game, while empowerment (3.03) and agency (2.59) were valued as secondary preferences among participants.

The evaluation asked also whether participants were interested in the game and whether they believed the game was effective in communicating about climate change.

Interest in Playing the Full Version of the Game. All participants expressed interest in the game, with 69% saying yes and 31% maybe.

Effectiveness of the Game in Educating Climate Change. All participants agreed that the game effectively communicates climate change and sustainability, highlighting its success in delivering educational content in an engaging manner.

6.4 Qualitative Analysis

The qualitative data from the user test provided further insights into the game concept. A thematic analysis was conducted where five codes were identified from 29 responses, yielding 55 coded phrases which were categorized into three main themes, presented with their percentages in Table 8. The key themes from the analysis are:

1. **Effective serious game design for climate change communication and engagement.** It highlights the game's role in enhancing climate change education and promoting real-world impact and behavioral change.
2. **User engagement in gameplay.** It indicates that the game is engaging and interactive, employing gamified features and storytelling.
3. **UCD principles for climate change games.** It emphasizes the importance of user-friendly design elements, focusing on simplicity and accessibility.

Table 8. Thematic analysis of the participant feedback.

Codes	Themes	Coverage
Education and Awareness	Effective Serious Game Design for Climate Change Communication	56%
Real-world Impact and Behavioral Change		
Engagement and Interactivity	User Engagement in Gameplay and Learning	35%
Gamification and Storytelling		
Simplicity and Accessibility	UCD Principles for Climate Change Games	9%
	Total	100%

Feedback from the participants shows that the game prototype effectively engages users and communicates climate change while utilizing UCD principles in game design. Participants (Ps) noted that it provides valuable insights into complex climate topics. One

participant stated, "*It will educate people what measures to take in reducing climate effects, what kind of issues will cause climate issues, etc*." (P15), emphasizing the game's potential to inform about practical solutions.

The game offers an engaging way to learn about climate change, simplifying complex topics, as one participant noted: *"This game provides an interactive and engaging way to learn about climate change and sustainability, making complex topics easier to understand and apply in real life"* (P19). Another added, *"I think while playing the game and accomplishing given challenges, users are collecting knowledge and improving their awareness of protecting the environment and sustainability"* (P21).

Related to the second theme, participants found gameful approach to learning more engaging than traditional methods. *"Because it is enjoyable than listening or reading about climate change news or articles. It is interactive, and players can see the effect of their actions immediately"* (P6). "*I believe it's very effective to use gamification to educate people on climate change and sustainability. Because it's difficult to take attention of people for these kinds of topics using traditional methods."* (P7).

Additionally, the engagement is also linked with curiosity and motivation for continued play. One participant reported, "*Because it is engaging and makes users curious about the next steps. So it will eventually teach about climate change and sustainability"* (P25). The ability of the game to maintain interest and motivation to learn is critical to influence behavior and to raise awareness.

Participants valued the storytelling and narrative-driven approach. "*The game has included storytelling related to climate change and sustainability. It is not like reading a report. So users can play the mini-games while getting an understanding of it. I think this is an interactive way to get user attention to the main topic*" (P28). "*It teaches you the importance of climate change, and also through the games and the advice by NPCs, we learn different ways to tackle existing issues and also about sustainability*" (P29). *"The narratives give a good understanding of how the problem affects each individual"* (P6). This feedback highlights that user engagement in gameplay directly correlates with interest in climate change and learning, fostering both curiosity and action.

The third theme emphasizes the importance of UCD principles in climate change games, focusing on simplicity, accessibility, and user-friendly features. While direct quotes were not elaborated in this direction, the interaction design and user-centeredness aspects were integrated in their feedback by using words such as "good understanding", "immediate feedback", "interactive", "easier to understand". The positive feedback included also suggestions that design elements like experiential learning, intuitive design, and clear navigation made the game engaging and easy to use, enhancing its effectiveness as an educational tool.

Recommendations for Changes to the Prototype. Participants suggested improving *EcoLand's* user experience by simplifying text, standardizing elements, enhancing button responsiveness, and adding interactivity. Future updates should include animated storytelling, voiceovers, consistent graphics, larger buttons, and reward animations. These insights highlight the importance of engaging storytelling and cohesive design in serious games, as well as the benefits of early user involvement and iterative refinement for effective climate change communication tools.

7 Discussion and Conclusions

We adopted a DSR research methodology to design a climate change engagement serious game. To address RQ1, we conducted a literature review and game analysis to create recommendations and a framework for climate engagement game design, contributing to HCI and UX knowledge. For RQ2, we applied this framework in developing a structured, staged process model for UCD of the serious game. This process, applied in the *EcoLand* prototype, aimed at improving climate change communication and making environmental education engaging. The development process followed iterative UCD practices, including prototyping, user involvement and structured evaluation. User testing involved a sample of participants aged 18 and above and combined both quantitative and qualitative data collection. Employing DSR methodology, incorporating literature review, game analysis, prototype development, and user evaluation, the study makes both theoretical and empirical contributions to HCI and UX research.

7.1 Implications for Game Design

The structured design process and conceptual framework enabled focusing on important aspects in the design, namely *gameful and learning experiences, engagement goals, user-centeredness, and context of use*. The structured evaluation highlighted that elements such as minigames, feedback, rewards, and level progression supported *engagement* and *learning*, while narrative-driven and scenario-based learning made climate issues *relatable* and *actionable*.

Playability was embedded in the design of the game story, game play, mechanics and usability [52] through careful design of the game flow and game loops by following the proposed design recommendations regarding narrative and engagement, social interactions, learning, real-world relevance and scientific accuracy, long-term engagement, ethical design, etc. However, formal evaluation of playability through heuristics or user testing of relevant criteria [53,54] remains for future work.

Emotion-oriented experiences [55] lead to sustained gameful engagement, while a staged emotional, cognitive and social engagement [15] ensures a more effective and longer-term engagement with the topic. We believe that these elements can or should be integrated through *designing gameful and learning experiences* and *engagement goals*. A design process should also incorporate attention to the *context of use* as well as *user-centered design principles, including iterations with users and ethical design,* as shown in the conceptual framework.

The GDLC model used in this study aligns with structured, feedback-driven cycles for serious game development as described by [40]. It provides a tailored approach for climate education games. Positive feedback and evaluation results affirm the model's effectiveness and practical value in designing engaging climate games.

The positive empirical results confirm that serious games can successfully bridge the gap between awareness and action when designed with engagement and learning goals in mind and following UCD principles and process. The *EcoLand* prototype incorporated narrative-driven gameplay, reward systems, and simulations which are the

elements found to be effective in prior works [9]. In *EcoLand*, scenario-based learning helps players understand the impact of their decisions, fostering behavioral change.

Three key themes emerged from the feedback: linking game elements to real-world behaviors, emphasizing interactive storytelling for engagement, and prioritizing simplicity and accessibility through user-centered design. These insights highlight the importance of delivering credible content in an engaging manner and the value of user involvement in the design process.

7.2 Limitations

EcoLand prototype is still in early development and needs refinement for broader use. While the game's content is generally accurate, it relies on publicly available data and would benefit from expert collaboration in climate science and economics. The convenience sample primarily included users aged 18–44, limiting the findings' generalizability to other age groups and demographics. The study also did not assess the long-term effectiveness of the game in maintaining user engagement, nor did it separately assess playability, providing directions for future research.

7.3 Conclusions and Future Work

This study demonstrates the potential of serious games as effective tools for climate change communication. Through the design and evaluation of the *EcoLand* prototype, the research highlights how integrating UCD and game design principles can significantly enhance user engagement, awareness, and motivation for climate action. Positive evaluation results validate the conceptual design framework and the structured GDLC model, confirming their effectiveness and relevance for designing engaging and educational games in this context.

The study contributes with a structured GDLC and ten design recommendations grouped into a conceptual design framework, validated by the positive user reception of *EcoLand* prototype. These tools offer valuable guidance for future developers and researchers aiming to address environmental issues through interactive media.

For future, we aim to develop the game by investigating further and designing the links between the design elements in the conceptual framework and actual gameplay and user experiences, including designing for a specific use context such as high school learners and citizen science. Furthermore, we are interested to examine and understand what triggers players interest in higher level engagement such as empowerment and agency and how playability affects engagement with climate change. Collaboration with climate and financial experts is essential to ensure factual accuracy and credibility. Additionally, longitudinal studies should evaluate the lasting impact of these games on user behavior and climate literacy.

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