

Designing Adaptable Playful Experiences for Climate Engagement: Lessons from NEUROCLIMA Play Ecosystem

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Abstract: Climate change constitutes a complex phenomenon that impacts various aspects of human life. Consequently, climate literacy and engagement are inherently multifaceted and multi-contextual as well. Climate change engagement therefore requires educational tools and resources that can reach diverse audiences across formal, informal, and community-based settings. While playful learning experiences have gained increasing attention as mechanisms for climate education and engagement, many are often designed for specific contexts, limiting their adaptability and flexibility of reuse. This paper presents a design case study of the NEUROCLIMA Play ecosystem, a playful climate engagement ecosystem comprising the NEUROCLIMA Play interactive learning modules and ClimateQuest, a physical board game, designed to support climate knowledge, discussion, and collaborative engagement around climate-related challenges across multiple learning environments. This study argues that designing for adaptability should be considered a core objective in the development of playful experiences intended to support climate awareness and engagement. Drawing on project documentation and design artefacts, this study analyses the design process, reflecting on key development decisions, and challenges encountered during the development process to examine how adaptability was addressed as a central design concern. The analysis identifies key design challenges related to diverse audiences, multiple contexts of use, different facilitator profiles, scientific accuracy and playability, shows how these challenges were addressed and then proposes practice-informed design principles for designing adaptable playful climate engagement experiences. The findings contribute to the growing literature on serious games and playful learning for climate literacy, engagement and societal impact by providing practical guidance for researchers, educators, and practitioners seeking to design playful interventions that can be deployed across a range of educational and public engagement contexts.

Keywords: Climate literacy, Game-based learning, Board games, Playful learning, Design principles

1. Introduction

Playful learning experiences are increasingly being used as a climate education and engagement approach because they enable complex and abstract climate challenges become tangible, relatable, and engaging (Gabriel & Schmölze, 2022; Bocu et al., 2022). This approach employs narratives, feedback loops and gamified elements to support experiential learning by letting players test choices, explore scenarios, and learn through consequences. Playful experiences also create opportunities for learners and citizens to dialogue and reflect on climate-related challenges, including co-produced understanding among stakeholders and discussion of real-life climate issues (Flood et al., 2018; Galeote & Hamari, 2021). In this context, playful experiences function as engagement tools that support communication, collaboration, and public participation around climate adaptation.

Many games and playful learning experiences are developed for specific audiences, learning objectives, or implementation contexts. While this can make learning effective within a particular setting, it may also limit adaptability, reuse, and scalability across other environments and contexts. This is particularly important for climate engagement which involves heterogeneous target audiences, including students, professionals, and the public (Gerber et al., 2021) and where learning and participation often take place across formal, informal, and community-based settings such as schools, museums, libraries and community workshops (Zummo et al., 2024). To design playful experiences that can travel across these settings, it is therefore vital to design for adaptability.

Addressing adaptability as a core design challenge, this paper examines how playful climate engagement experiences can be intentionally designed to support multiple forms of use across multiple audiences and contexts. To examine this issue, the paper presents a design case study of the NEUROCLIMA Play ecosystem, an ecosystem consisting of interactive learning modules developed to introduce various climate adaptation

themes to different learner groups and a physical board game designed to support climate literacy, dialogue, and engagement. Together, these tools form a modular and adaptable playful engagement ecosystem that can be used across formal, informal, and community-based contexts. This case study is guided by the following research questions:

RQ1: What design challenges emerge when developing adaptable playful experiences for climate engagement across diverse audiences and settings?

RQ2: What design principles can support the development of adaptable playful experiences for climate engagement?

2. Literature Review

2.1 Interactive Modules and Board Games for Climate Engagement

Playful learning experiences represent a spectrum of learner-centred activities based on playful and game elements, narratives, and/or gameplay that enable learners to acquire knowledge and skills while engaging in a ludic, creative, and exploratory state (Foti et al., 2023; Li & Kangas, 2024). Playful experiences for climate engagement are generally deployed across, hybrid, digital and physical modes and take multiple forms, including interactive modules, digital games, simulations, gamified applications, role-playing activities, card games, board games, and collaborative and school-based learning workshops (Douglas, 2020; Galeote et al., 2021).

Interactive modules and board games represent two distinct yet complementary approaches because they support different but complementary forms of engagement. Interactive media provide structured, self-paced, and multimedia-rich experiences, while the social nature of board games afford spaces for dialogue, collaboration, and collective reflection. They are useful for group-based learning, negotiation, and collaborative sense-making (Higgins & Mcfeetors, 2019). In climate education and adaptation contexts, physical board games can help participants explore trade-offs, compare perspectives, and discuss possible responses to climate-related challenges. Because board games often require players to interact directly with one another, they can support social engagement in the form of dialogue, cooperation, and reflection on collective action.

Existing research on playful and gamified climate engagement experiences emphasise that their effectiveness depends on the quality of the design process, the fit between the game format, gameplay and the engagement objective (Romero et al., 2020), the characteristics of the target audience (Kalmpourtzis, 2018), and fit with the context in which the activity is implemented (Galeote et al., 2023). While these studies provide useful guidance on the design of climate-related games and playful experiences, recent attention has been paid to adaptability as a specific design concern (Algayres et al., 2021). This points to a need to examine how playful climate engagement resources can be designed for use across different audiences, facilitators, formats, and formal or informal learning contexts.

2.2 Adaptability as a Design Challenge

In the climate games literature, the term adaptability is used in different ways. In some cases, it refers to the role of games in helping individuals, communities, or decision-makers understand and respond to climate adaptation challenges (Hugel, 2022). In other cases, it refers to the adjustment of a learning or engagement experience to a particular audience, setting, or implementation condition. This paper adopts the second meaning. Adaptability is understood here as the capacity of a playful experience to be used and adjusted across different audiences, facilitators, formats, and learning or engagement contexts without requiring substantial redesign (Flood et al., 2018; Nabong, 2024).

The impact of playful climate engagement is not guaranteed by the presence of gamified or playful elements alone but on their fit to context. Their impact depends on whether the experience matches the audience's prior knowledge, age, language, motivation, available time, social setting, and facilitation conditions (Mylonas, 2021; Galeote et al., 2023). A playful experience that works well in one classroom or workshop may not necessarily work in a museum, library, community event, or public awareness campaign. This is particularly relevant for climate engagement because climate learning and participation take place across multiple formal, informal, and community-based settings which differ in important ways.

In the literature, adaptability is understood as a multidimensional concept. Audience adaptability refers to the capacity of a playful experience to match different age groups, knowledge levels, language needs, and

participant roles (Mylonas, 2021; Nabong, 2024). Context adaptability refers to the capacity to fit different settings, such as schools, community spaces, public engagement events, or policy-oriented workshops (Mylonas, 2022). Facilitation adaptability concerns the extent to which guidance, instructions, and debriefing can be adjusted to suit different facilitators and participant groups (Hognon, 2026). Content adaptability refers to the ability to select, simplify, expand, or reconfigure climate topics according to the goals of the activity (Godfrey, 2023; Schattman et al., 2019). Engagement adaptability encompasses the capacity to support multiple participation modes, demonstrated by cooperative games, collaborative learning, civic science, and community-engaged education that support knowledge gains, discussion, collaboration, reflection, and collective decision-making (Vázquez-Vílchez et al., 2021; Gonzalez et al., 2023).

These dimensions highlight why adaptability should be treated as a core design concern. Too little tailoring can leave school constraints, educator capacity, age differences, language needs, or local engagement conditions unaddressed. At the same time, excessive customisation can make playful resources difficult to scale or reuse. The design challenge, therefore, lies in creating playful climate engagement experiences that are structured enough to preserve their educational and engagement purpose, but flexible enough to be adapted across different audiences, facilitators, and contexts.

3. Methodology and Case Description

3.1 Reflective Design Case Study

This study adopts a design case study approach. Design cases are recognised as a way of documenting and communicating design knowledge by making visible the artefacts, constraints, decisions, and situated reasoning involved in the development of educational and interactive experiences (Boling, 2010; Howard et al., 2012). This approach was deemed appropriate for this paper because the focus is on understanding how design decisions were made in response to practical, pedagogical, and contextual challenges.

The analysis considers the design challenges that shaped the development process, the responses adopted by the design team, and the principles that emerged from these decisions. This approach is particularly relevant because adaptability was a design issue that influenced decisions during development of the ecosystem. The analysis is guided by the research questions highlighted in the introduction section.

3.2 Case selection and Description: The NEUROCLIMA Play Ecosystem

The NEUROCLIMA Play ecosystem was selected as the case for this study because it provides a relevant example of a modular and adaptable playful engagement ecosystem designed for use across multiple climate learning and engagement contexts. The ecosystem consists of NEUROCLIMA Play interactive learning modules and a physical board game titled “*ClimateQuest*”. The modules introduce climate-related themes through structured digital learning experiences, while ClimateQuest provides a board game format for engaging with climate-related questions and challenges. Together, these resources form the case examined in this paper. This ecosystem was developed within project NEUROCLIMA, a horizon Europe funded project aimed at promoting citizen’s participation and supporting public understanding, participation, and decision-making around climate adaptation.

3.2.1 NEUROCLIMA play modules

The NEUROCLIMA Play modules are interactive learning resources covering 6 climate-related themes. Each module includes introductory content, learning objectives, interactive activities, visual or multimedia elements, and a playful quiz component. The modules are organised according to different target groups and themes. Table 1 provides an overview of the modules, their themes and main target groups.

Table 1: Overview of the modules, their themes, main target groups, and intended engagement functions

Module	Climate Theme	Target Group
Module 1	Agro-food systems	Children / younger learners
Module 2	Energy	Adults / general learners
Module 3	Water	Adults / general learners

Module	Climate Theme	Target Group
Module 4	Disinformation and misinformation	Teenagers / young people
Module 5	Forest fires	Children / younger learners
Module 6	Behavioural change	Teenagers / young people

3.2.2 ClimateQuest board game

ClimateQuest is a printable physical board game consisting of a game board, question cards, challenge cards, instruction booklet, and supporting facilitator materials. The game combines knowledge-based questions with challenge-based prompts. Question cards address themes connected climate change, while challenge cards invite players to respond to additional tasks or scenarios. The game can be played in 4 modes i.e single-player without challenge cards, single-player with challenge cards, team play without challenge cards, and team play with challenge cards. ClimateQuest is intended for use in different learning and engagement activities, including classroom sessions, workshops, public awareness events, and community-based activities.



Figure 1: ClimateQuest Question Card

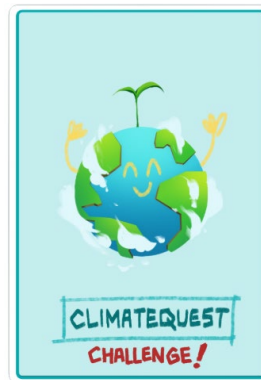


Figure 2: ClimateQuest Challenge Card

3.3 Data Sources

This analysis draws on a range of project documentation and design artefacts produced during the development of NEUROCLIMA Play ecosystem. The first set of data sources consisted of project documentation related to the design and development of the NEUROCLIMA Play ecosystem. This included internal planning documents, task descriptions, development notes, presentations, collaborative development records, including meeting notes, partner feedback, internal review comments, design discussions involving members of the interdisciplinary team and project deliverable materials outlining the intended objectives, target audiences, and design strategy of the tools. These documents provided insight into the broader project context and the design intentions guiding the development process.

The second set of sources included design artefacts associated with the tools in ecosystem. For the modules, these included module outlines, storyboards, learning objectives, content structures, interactive activities, visual assets, and instructional materials. For the board game, the artefacts included the game concept notes, rules, question cards, challenge cards, board design, facilitator guidance, and printable game materials. These artefacts were examined to understand how climate content was translated into interactive and playful formats. Together, these sources were used to reconstruct the design process and provided a basis for analysing the development of NEUROCLIMA Play ecosystem.

3.4 Analytical Approach

The analysis followed a reflective process focused on identifying the design challenges, design responses, and emerging principles that shaped the development of NEUROCLIMA Play ecosystem. The reflective approach is informed by Schön's theory of reflection on practice, which emphasises how professional knowledge can emerge through reflection on action in complex and dynamic design situations (Ramage, 2017). The aim was to

move from a description of the case toward a synthesis of design knowledge that could be useful for improving practice. The reflective analysis was operationalised through a challenge–response–principle sequence.

In the first stage of analysis, project documentation and design artefacts were reviewed to reconstruct the development process. This stage helped identify the main design requirements that informed the development of the NEUROCLIMA Play. The second stage focused on identifying recurring design challenges. These challenges were identified through the systematic identification of repeated patterns and tensions across textual and artefactual data (Braun & Clarke, 2006). Attention was given to recurring issues related to audience diversity, implementation context, facilitator expertise, scientific accuracy, accessibility, playability, and forms of engagement. A challenge was considered significant when it appeared across more than one source of documentation.

The third stage examined the design responses adopted to address the identified challenges. a principle was formulated only when a design challenge appeared across more than one source of documentation and could be linked to concrete design responses within the NEUROCLIMA Play ecosystem. These challenge-response relationships were then abstracted into broader practice-informed principles intended to offer guidance beyond the NEUROCLIMA PLAY ecosystem case to broader guidance for future designers, educators, and practitioners.

4. Designing for Adaptability: Key Design Challenges, Responses, and Emerging Principles

4.1 Designing for Diverse Audiences, Scientific Accuracy and Playability

Climate adaptation is a complex topic that includes scientific concepts and data, behavioural issues, and environmental risks, and social responses. Presenting this content in the same way to young learners, adults, educators, and general citizens would risk making the material either too simple for some audiences or too complex for others. More so, climate-related playful experiences should be grounded in scientifically verified data. If scientific content is oversimplified, the game may become easier to play but less educationally valuable; if it is too technical, it may preserve accuracy but remain too abstract for players to understand and engage with meaningfully. Therefore, one of the main design challenges that emerged was the need to develop playful climate resources for audiences with different ages, levels of prior knowledge, and learning needs and to balance scientific accuracy with playability

To address this challenge, the development process included creative collaborative workshops with climate experts, potential target groups and project partners. These workshops were used to identify, discuss, and rank climate-related topics according to their relevance, complexity, and suitability for different audiences and age groups. This process helped the design team determine which topics could be meaningfully introduced to younger learners and which required more advanced levels of prior knowledge or abstraction. The creative workshops resulted in organising the NEUROCLIMA Play modules around 6 different climate themes for 3 target groups. For example, topics such as Agro-food systems and forest fires were developed for younger learners, while themes such as energy and water were directed toward adult or general learners. Modules on disinformation, misinformation, and behavioural change were positioned for teenagers and young people. This distribution allowed the ecosystem to address climate adaptation through multiple entry points. The potential use of the resources across different European contexts was also supported through translation into multiple languages.

Furthermore, scientific content was translated into shorter learning sequences, relatable examples, stories, scenarios, questions, and challenges. This made it possible to introduce complex issues in ways that were easier to understand and more suitable for playful engagement. Interdisciplinary input was important in this process. Climate experts supported the validation of content to ensure that the scientific information remained accurate and relevant, while educators and designers helped translate this content into learning objectives, activities, and playable scenarios and formats.

Design Principle: Design for audience-sensitive and scientifically grounded play. Adaptable climate engagement experiences should not assume a single ideal learner. They should provide different thematic, linguistic, and activity-based entry points that allow diverse audiences to engage with climate adaptation at an appropriate level of complexity, while ensuring that playful engagement remains grounded in scientifically reliable and socially relevant content.

4.2 Designing for Multiple Contexts

A second design challenge concerned the range of possible implementation contexts. Climate literacy itself is inherently multi-contextual, as it develops across formal education and informal learning contexts. Considering this, the team needed to design the tools to be usable across formal, informal, and community-based environments. These contexts differ in parameters such as available time, space, technological infrastructure, facilitation conditions, and participant expectations. In response, the ecosystem was developed as a modular set of resources that can be recombined as needed. The play interactive modules can be used individually according to the theme, audience, or objective of a session, while ClimateQuest board game can be used after the modules, alongside selected module content, or as a separate engagement activity entirely. This structure allows facilitators to adapt the experience to different contexts. For example, a school session may use a module as part of a structured learning activity, while a public engagement event may use selected ClimateQuest questions or challenges to initiate discussion around climate adaptation.

Additionally, the digital modules were designed to provide structured and self-paced access to climate-related content, while the printable board game supports offline, face-to-face group interaction. This digital-offline combination expands the possible settings in which the ecosystem can be used. The modules may be useful where digital access and individual or guided learning are possible, while the board game may be easier to deploy in workshops, community activities, or physical public-facing settings where social interaction is central and technological conditions may vary. Although the modules and ClimateQuest can be used together, the ecosystem was designed to not require all users to complete all modules before playing the game. This was important because informal settings often involve shorter sessions, mixed audiences, or participants who join an activity without prior preparation. By allowing the modules and game to be used independently or in combination, the ecosystem can support both structured learning and more open-ended public engagement.

Contextual flexibility was also supported through customizable question cards in ClimateQuest board game. These cards allow facilitators to create or adapt questions according to the climate topic, lesson content, or engagement focus of a particular session. For example, a teacher may fill up the customizable question cards based on a climate topic previously taught in class, while a workshop facilitator may adapt questions to reflect the theme of a public engagement event.

Furthermore, four gameplay modes were built into ClimateQuest. These modes allow facilitators to adapt the game to different group sizes, timeframes, levels of prior knowledge, and engagement goals. For example, a short classroom session may use the single-player mode without challenge cards for quick knowledge reinforcement, while a workshop or full-class activity may use team play mode with challenge cards to support deeper discussion and collaborative engagement.

Design Principle: Design for modular and contextual reuse. Adaptable playful experiences should be structured so that components can be used independently, combined flexibly, or adapted to fit different delivery contexts without changing the core design.

4.3 Designing for Different Facilitators

A third design challenge concerned the range of possible facilitators who may use the NEUROCLIMA Play ecosystem. In different implementation contexts, facilitators may include teachers, NGO staff, museum educators, community organisers or other public engagement practitioners. These facilitators may vary in their familiarity with climate adaptation, educational design and activity facilitation. As a result, the resources needed to be usable not only by climate or education specialists, but also by non-specialist facilitators working in diverse settings. The design team responded by providing structured and ready-to-use resources that reduce the burden on facilitators while still allowing them to personalize and guide the experience meaningfully. The NEUROCLIMA Play modules include pre-developed content, learning objectives, interactive activities, and short assessment components. Similarly, ClimateQuest includes question cards, challenge cards, instructions, and supporting customizable materials. Instructional facilitation manuals were also developed to guide facilitators in preparing, introducing, running, customizing and concluding the activities. These manuals provide practical support for using the resources in different learning and engagement contexts.

In ClimateQuest, facilitation flexibility was further supported through simple rules, board game mechanic, and structured prompts. The game uses a recognisable “roll the dice and move across the board” mechanic, combined with answering questions and responding to challenges. This mirrors common entertainment board games, making the activity easier for facilitators to explain and easier for participants to understand. At the same time, the rules and play modes allow facilitators to adjust the experience.

Design Principle: Design for facilitation flexibility. Adaptable playful climate engagement resources should be usable by non-specialist facilitators while preserving the integrity of the learning experience through clear instructions, ready-to-use materials, familiar mechanics, and guided discussion prompts.

5. Discussion

The analysis shows that adaptability is a design concern that shapes design decisions about audience, context, facilitation, content, language, and gameplay. It also suggests that adaptable playful climate engagement resources need to be structured enough to preserve their educational purpose, while remaining flexible enough to be reused across different settings. This is particularly important because climate literacy and engagement occur across classrooms, workshops, public events, community spaces, and other informal learning environments. In such settings, participants, facilitators, timeframes, and engagement goals may vary considerably. Designing for adaptability therefore requires anticipating these variations during design and development phase. Overall, this design case contributes to discourse on adaptable playful climate engagement tools and resources by foregrounding adaptability as a design principle (Galeote et al., 2025). While existing work often focuses on the effectiveness of climate games or the use of game elements to increase engagement, this paper highlights the importance of designing resources that can travel across contexts and propose practice-informed principles for designing such resources. The proposed principles are not intended as universal rules, but as practice-informed guidance for designers, educators, and engagement practitioners developing playful climate resources for diverse and changing settings.

This study is limited by its reflective design case study approach. The analysis is based on project documentation, design artefacts, and reflection on the development process of NEUROCLIMA Play and ClimateQuest. It does not include an empirical evaluation of learning outcomes, participant experience, facilitator use, or behavioural impact. As a result, the design principles proposed in this paper should be understood as practice-informed insights rather than validated guidelines. As part of the next phase of the project, the NEUROCLIMA Play ecosystem is planned to be piloted in four European countries. These pilots will provide an opportunity to examine how the modules and ClimateQuest are used across different educational, cultural, linguistic, and community-based contexts. Future empirical work could collect data from participants and facilitators through observations, questionnaires, interviews, and post-activity reflections. This would make it possible to assess the usability of the resources, the relevance of the proposed design principles, and the extent to which the ecosystem supports climate literacy, discussion, and engagement across diverse contexts.

6. Conclusion

This paper presented a reflective design case study of the NEUROCLIMA Play ecosystem, comprising interactive learning modules and the ClimateQuest board game. The study examined how playful climate engagement resources can be designed for use across diverse audiences, facilitators, and contexts. The analysis shows that adaptability should be treated as a central design concern rather than a later implementation issue. Key design responses included modular resources, multiple modes of play, customizable materials, facilitation guidance, familiar gameplay mechanics, multilingual resources, and interdisciplinary input. From these responses, the paper identifies and contributes practice-informed principles for designing adaptable playful climate engagement experiences, including multiple audience entry points, modular and contextual reuse, facilitation flexibility, and scientifically accurate yet accessible play. These principles offer guidance for researchers, educators, designers, and practitioners developing serious games and playful learning resources for climate adaptation and wider societal engagement.

Ethical Declaration: No formal ethical clearance was required for this study

AI Declaration: AI tools were used only for basic formatting, language polishing, and minor editing support during the preparation of this paper. All substantive ideas, analysis, design reflections, and final decisions were developed and reviewed by the authors. The authors take full responsibility for the content of the submitted paper.

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