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A Serious Game Proposal for Raising Awareness on Sustainable Development in the Built Environment

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Abstract

Interactive serious games enhance science-based communication and promote deeper learning about sustainable development. It is yet undiscovered that how can AI-augmented interactive experiences enhance the engagement and spread awareness. This study proposes an AI-augmented digital serious game in public installation format. First, the study introduces a serious board game centered on Sustainable Development Goal (SDG) 11 to test the learning aspects and the engagement of the game. The study hypothesizes that a serious game with a clear message, engaging mechanics, and appealing design can significantly enhance understanding of sustainability's relevance to everyday life. Using a Research through Design (RtD) approach, the study incorporated iterative feedback from pilot tests. These tests highlighted the effectiveness of problem-solving and group discussions in fostering engagement. The insights directly informed the design of the digital version, which emphasizes streamlined and accessible gameplay.

Keywords

Sustainability, built environment, serious games, eco-didactic, game-based learning, AI

Introduction

Raising awareness about sustainable development is becoming increasingly urgent in the face of accelerating climate change and environmental degradation. In fostering sustainability literacy, interdisciplinary education, systems thinking, project-based learning, and civic engagement are among the most recognized approaches (Boarin & Martinez-Molina, 2022). Experimental approaches, such as self-directed learning, museological learning, game-based learning, and gamification could create engaging experiences regarding spreading public awareness on sustainability in the built environment (Boragine, 2023; Falk & Dierking, 2000; Kolb, 2014; Sailer et al., 2017). However, how these methods connect with broader audiences in informal or public settings and how digital technologies and Artificial Intelligence can enhance the experiences remain under discovered. Therefore, this study aims to explore learning mechanisms and engagement strategies of a serious board game that teaches sustainable development in the built environment. Consequently, the findings from the serious game are used to develop an AI-powered interactive digital public installation for raising environmental awareness and promote sustainable development. Therefore, this paper presents the initial phase of a larger project that aims to develop an AI-enhanced digital installation for public use. The current study focuses on the analog and semi-digital prototypes used to explore effective gameplay elements and educational strategies. The outcomes of pilot tests inform the ongoing development of a digital version intended for deployment in public spaces.

According to the *Sustainable Development Report 2023* (Sachs et al., 2023), progress on SDG 4 (Quality Education) remains insufficient at the midpoint toward the 2030 Agenda (*Education*, 2015). Likewise, a 2022 Canadian survey on climate change education (Schwartzberg et al., 2022) revealed that 64% of respondents believe the education system is not doing enough to address climate change. These findings point to the need for complementary educational tools that promote public engagement and self-directed learning beyond formal institutions. Alternative educational tools such as serious games, have demonstrated effectiveness in simulation of complex subjects, specifically regarding sustainability in the built environment (Boragine, 2023; Dib et al., 2012; Dib & Adamo-Villani, 2014; Romano & Rogora, 2023). On the other hand, public realm offers unique opportunities for experiential learning and raising awareness through interactive installations, public art, and gamified experiences. Eco-art installations in particular have shown strong potential to engage citizens in environmental issues by transforming complex topics into accessible, multisensory encounters (Cucuzzella et al., 2020, 2021; Karimimoshaver et al., 2021; Lee, 2021). One notable example is Mary Miss's *Broadway: 1000 Steps*, which localized environmental issues and produced positive community outcomes (Miss, 2009). In the same token, interactive installations have demonstrated high public engagement (Horst, 2022; Ntalla, 2021; Olgen & Cucuzzella, 2024; van Renswouw et al., 2022), transforming public spaces into experimental playgrounds that would be open for many opportunities. Such initiatives demonstrate how the public realm can foster civic dialogue, learning, and behavior change.

Building on this potential, the study introduces the initial phase of an eco-didactic installation, drawing inspiration from eco-art as a means to advance urban sustainability education in the public realm. The central hypothesis is that a well-designed game, combining clear messaging, interactive mechanics, and aesthetic appeal, can significantly improve public understanding of sustainability in the built environment and its connection to everyday life. To test this, we developed and evaluated an analog board game based on SDG 11: Sustainable Cities and Communities, due to its relation to sustainable development in the built environment. This study understands sustainability in the built environment as combination of actions including designing, developing, constructing, and operating buildings and urban constructions in ways to decrease environmental impact. The game design was informed by a Research through Design (RtD) methodology and emphasized participatory development, iterative feedback, and interdisciplinary learning principles. RtD methodology is significant in this case due to its exploratory nature, allowing flexibility with iterative experimental testing which is suitable in designing and testing a serious game and an interactive digital installation (Godin & Zahedi, 2014; Koskinen et al., 2011; Zimmerman et al., 2007).

The remainder of this article structured as follows: Following section provides a literature review on playful and educational eco-experiences, establishing the theoretical grounding for the study. After the literature review, methodology is defined, including the research questions and objectives, the development of the game prototypes, participant sampling and ethical considerations, and the evaluation tools and experiment setup. Results section presents the findings from the focus group evaluation, the in-person playtest and survey results of Version A, and the survey results of Version B. Discussion section connects the outcomes to the design of a digital, AI-augmented eco-didactic installation intended for public engagement.

Literature Review: Playful and Educational Eco-Experiences

Environmental education has increasingly embraced experiential and participatory methods that emphasize active learner engagement. Falk and Dierking argue that self-directed, physically grounded learning experiences enhance knowledge retention and relevance, particularly in formal settings (2000). Such approaches are well-suited to public spaces and museums, where visitors interact with content through their senses, actions, and discussion.

Studies have consistently shown that interactivity and playfulness significantly enrich environmental learning, especially in informal contexts (Lesen et al., 2016; Ntalla, 2021; Wang & Chen, 2021). Regarding sustainability education in the built environment, the educational tools that use gamification (Deterding et al., 2011; Sailer et al., 2017) and serious games (Boragine, 2023; Polys et al., 2017) has shown significant potential in fostering environmental awareness, facilitating multifaceted systems thinking approach, by simulating real-life applications. Unlike gamification, which typically incorporates game elements into non-game settings, serious games are designed specifically with educational goals at their core (Den Haan & Van der Voort, 2018; Ouariachi et al., 2019; Stanitsas et al., 2019; Wouters et al., 2013). In sustainability context regarding the built environment, serious games have been found to increase learner engagement, promote interdisciplinary dialogue, and encourage long-term behavioral change (Gatti et al., 2019; Ho et al., 2022; Isaacs et al., 2008; Iyer-Raniga & Andamon, 2016).

Among many effective alternative educational approaches, board games, in particular, have shown strong potential for facilitating sustainability learning. Eisenack's *KEEP COOL* game enables players to simulate climate negotiations, integrating biophysical, economic, and political aspects of climate change (2013). The game encourages interdisciplinary communication and has been used successfully in academic and public settings. Similarly, Tsai et al.'s developed *Be Blessed Taiwan*, which teaches the trade-offs between economic development and biodiversity preservation (2021). Players reported increased understanding of conservation concepts and gained policy decision-making and teamwork skills. Fjællingsdal and Klöckner evaluated four environmental-themed board games and found that they effectively simplified complex sustainability concepts and stimulated reflection on cause-effect relationships in environmental systems (2020). Cheng et al. designed a problem-based board game on water resource adaptation, which used role-play to enhance responsibility, negotiation, and critical thinking (2019).

Other forms of game-based learning, specifically in the context of teaching sustainability in the built environment, such as digital games, have proven effective, supporting the traditional lectures on the subject (Ayer et al., 2016; Juan & Chao, 2015; Lameras et al., 2013). These examples show the potential of the educational value of games that are purpose-built for sustainability learning.

Beyond analog games, digital and immersive experiences also support eco-didactic goals. Ntalla explored play and playfulness in an interactive museum installation titled *The High Arctic Installation*, noting that multisensory environments shifted adult perceptions of learning and engagement (2021). Participants who initially perceived play as "childish" became more enthusiastic, suggesting the transformative potential of spatial and sensory-rich formats. Wang and Chen demonstrated that interactive, multi-level tablet-based games for marine education

increased both engagement and correct knowledge retention rates (81,7% post-game accuracy), underscoring the value of interactive technology in science education (2021).

Emerging technologies such as Artificial Intelligence (AI) also hold promise for enhancing serious games. AI can personalize feedback, simulate complex scenarios, and support real-time interactions in public installations. While few studies have yet explored AI-integrated eco-didactic tools, early examples suggests that AI can act as both guide and collaborator, adapting content dynamically to player choices and offering tailored insights (Audry, 2021; Boragine, 2023).

In a preliminary study at Montreal's Biosphere Environment Museum, the authors evaluated interactive installations demonstrated in two exhibitions: *Eco Lab* and *This is Not an Umbrella* (Olgen & Cucuzzella, 2024). A comparative analysis between digital and analog interactive installations and non-interactive installations were conducted within the study. Results show that analog and multisensory installations generated more dialogue, engagement, and collaborative learning than passive or purely digital ones. Participants gravitated toward more playful interactive experiences than mere touch screens, reinforcing the effectiveness of play-based environmental education.

Identified Gap and Study Contribution

While these examples demonstrate the pedagogical potential of board and digital games, there remains a lack of research combining serious game mechanics, AI-powered interactivity, and public realm installations for sustainability in the built environment education. This study addresses that gap by testing analog and digital prototypes of a serious game informed by SDG 11. It contributes to the literature by integrating participatory design, iterative development, and empirical evaluation into a framework for a future AI-powered interactive public installation.

Materials and Methods

This study adopts a Research through Design (RtD) methodology, which is particularly well-suited for educational interventions involving participatory design and iterative prototyping (Godin & Zahedi, 2014; Koskinen et al., 2011; Zimmerman et al., 2007). RtD enables the exploration of design as a method of inquiry, emphasizing learning-through-making and refining solutions based on stakeholder feedback. In this research, RtD provides a framework for developing, testing, and refining a serious game that integrates educational theory with real-world learner experiences.

RtD was chosen for this capacity to support participatory and iterative development in the context of sustainability education. By engaging students, educators, and interdisciplinary collaborators in the design process, the method ensures that the resulting game is grounded not only in theoretical principles but also in users' cognitive, social, and experiential needs.

Research Objectives and Questions

The study explores how game-based learning can support sustainable development education in the built environment in both formal and informal learning environments, particularly those within the public realm. The overarching goal is to evaluate the effectiveness of interactive and

didactic components, through board game designs, in the early development stages of an AI-powered eco-didactic installation. Specifically, the study is guided by two research questions:

- **Interactivity:** How can interactive gameplay elements, such as decision-making, negotiation, and collaboration, be integrated into a board game to maximize engagement and meaningful player interaction?
- **Didactic Aspects:** How can a game be designed to effectively convey sustainability principles, especially those related to SDG 11: Sustainable Cities and Human Settlements, while fostering critical thinking and collaborative learning?

Game Design and Prototypes

The serious game, titled Next-Gen Islands, was developed through three iterative stages, each building on the findings of the previous:

- **Version A:** A physical board game prototype emphasizing target-based challenges and collaboration tested in small, in-person focus groups.
- **Version B**: A digital, collaborative problem-solving adaptation developed using the Miro platform, tested in a virtual classroom to simulate collaborative gameplay.
- **Version C**: A planned AI-augmented digital prototype currently under development.

Both Version A and B contextualize SDG 11 through four thematic targets: housing, public transportation, green spaces, and environmental impact. The analog version features four fictional islands with each team acting as decision-makers for their island's sustainable development. Gameplay is designed to prompt discussion, argumentation, and justification, students solve randomly drawn problem cards using "action cards," all color-coded to represent SDG targets. Progress depends on the strategic allocation of limited resources, represented by dice rolls simulating government funding.

Version B simplifies these mechanics to prioritize dialogue and collaboration. Tested online during a virtual class, this version removed game competitiveness and time constraints, shifting the focus group deliberation and peer-reviewed decision-making. Students used breakout rooms to discuss problems and present solutions, which other teams would approve or reject. This version was also used to simulate future AI-driven interactions using Wizard of Oz prototyping, where facilitators manually replicated AI functions (e.g., prompts, reactions, dynamic content) (Dow et al., 2005).

Next-Gen Islands Board Game (Version A)

The Next-Gen Islands board game was developed to contextualize the four primary targets of SDG 11: Sustainable Cities and Human Settlements within an engaging, real-lime simulation (Figure 1). The game's pedagogical objective is to promote critical thinking and collaborative decision-making by challenging players to address urban sustainability issues through scenario-based gameplay. The game offers a competitive play where four groups of people compete to each other to first achieve the objectives.

Figure 1. Selected 4 targets of SDG 11

The game features four fictional islands, each assigned to a team of 2-3 players, who assume the roles of urban decision-makers. These islands are represented on the board (see Figure 4). The core mechanic revolves around resolving challenges drawn from key SDG 11 themes: housing, public transportation, green spaces, and environmental impact, through the strategic use of action cards. These pared with problem cards, both color-coded and categorized by SDG targets (Figures 2 and 3).

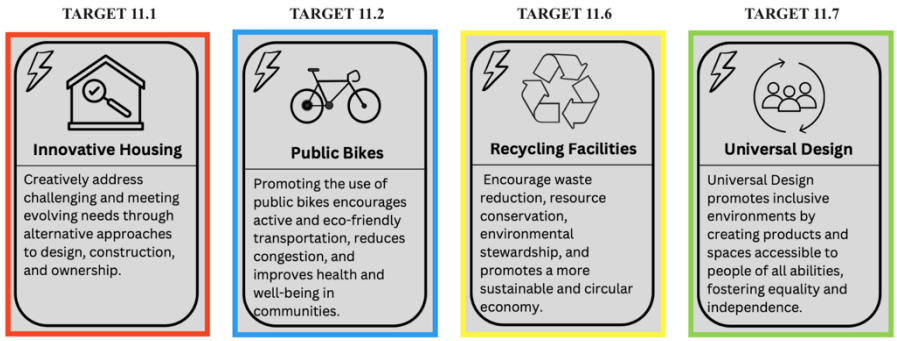

Figure 2. Examples of action cards categorized by targets

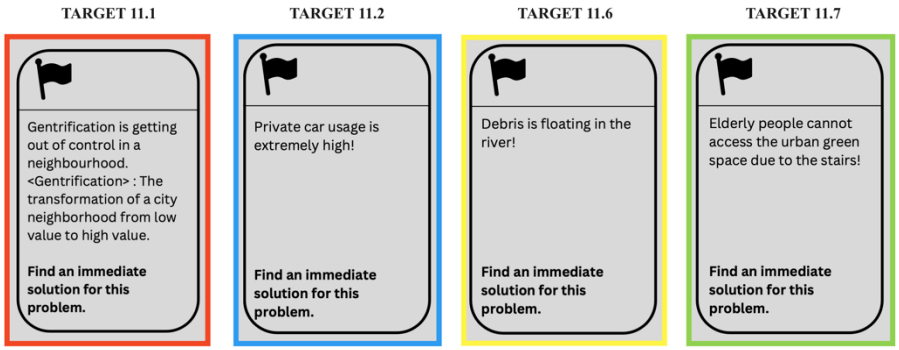

Figure 3. Examples of problem cards categorized by targets

Each team progresses by justifying their chosen actions to solve the assigned problems. They progress on the board. Funding, simulated by two dice, is allocated randomly based on island and target categories, representing the unpredictability of public budgeting. The board shows 4

themed paths, one for each target, on all the islands (Figures 4 and 5). This allows players to track their process in the game. These paths also show the amount of payment they need to do (1, 2, or 3 money tokens) to be able to implement their solution for the problems (Figure 4). Cross-category action cards may be used, but an added cost and with group approval.

The teacher plays a facilitative rather than authoritative role. They introduce the game, clarify rules, and provide guidance if needed. However, gameplay and discussion are led entirely by students, fostering autonomy and peer learning. Post-game debriefs are used to reflect on learning outcomes and strategy.

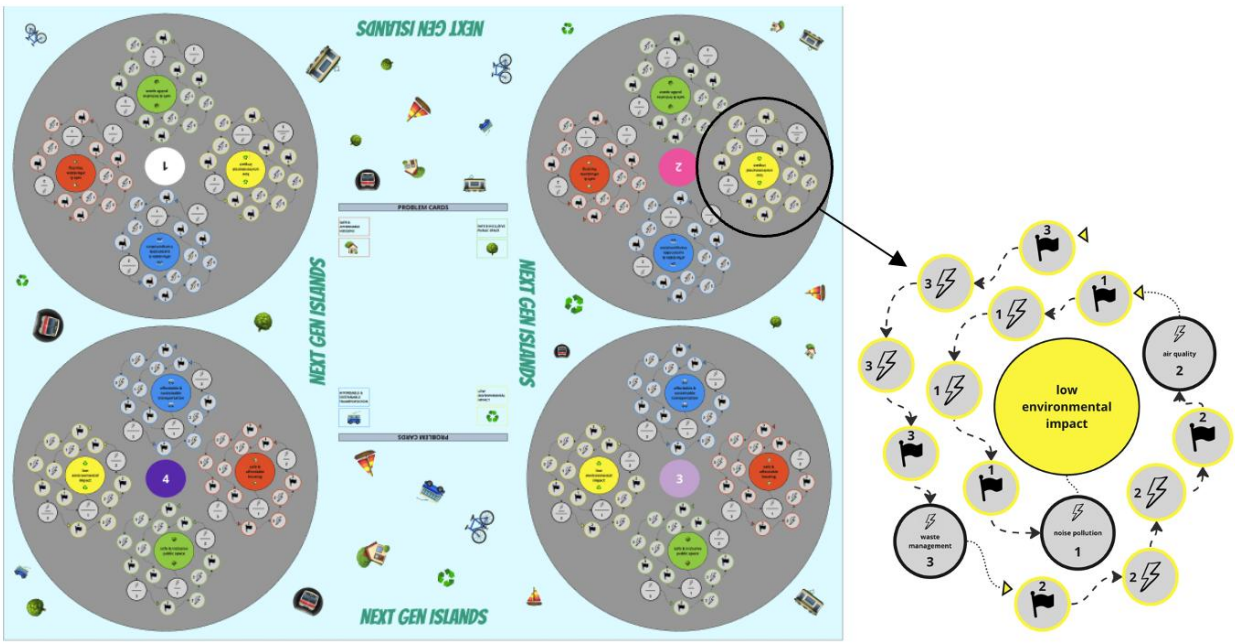

Figure 4. The board and one of the four target paths placed on each island on the board

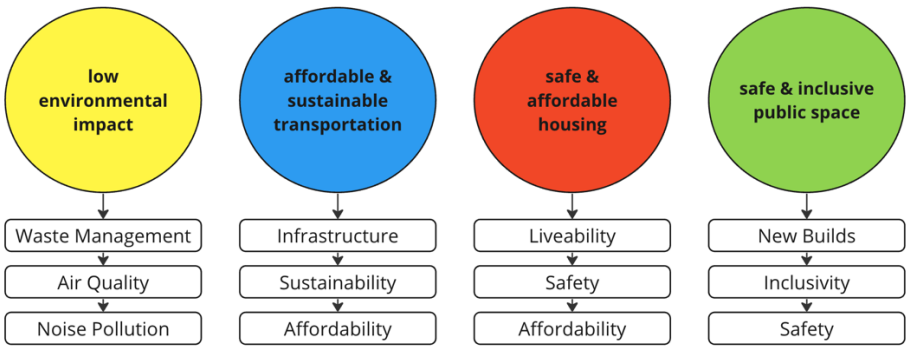

Figure 5. Different levels for each target

Digital Adaptation (Version B)

To simulate the collaborative and decision-oriented nature of a future AI-powered installation, a streamlined digital version of the game (Version B) was developed using Miro, a cloud-based

collaborative platform. Unlike the board game, Version B focuses exclusively on problem-solving and dialogue, eliminating the competitive element to prioritize cooperative learning.

Each team received a randomized problem card and all available action cards (Figure 6). Players collaborated in breakout rooms for five minutes to devise a solution using three action cards. Once reconvened in the main session, each group presented and justified their proposed solution. Other teams responded using emojis (thumbs-up or X) to simulate peer approval, mirroring the social validation process built into Version A.

This format was particularly effective for encouraging real-time discussion and peer critique, reflecting how such a system might operate in a digitally augmented public space.

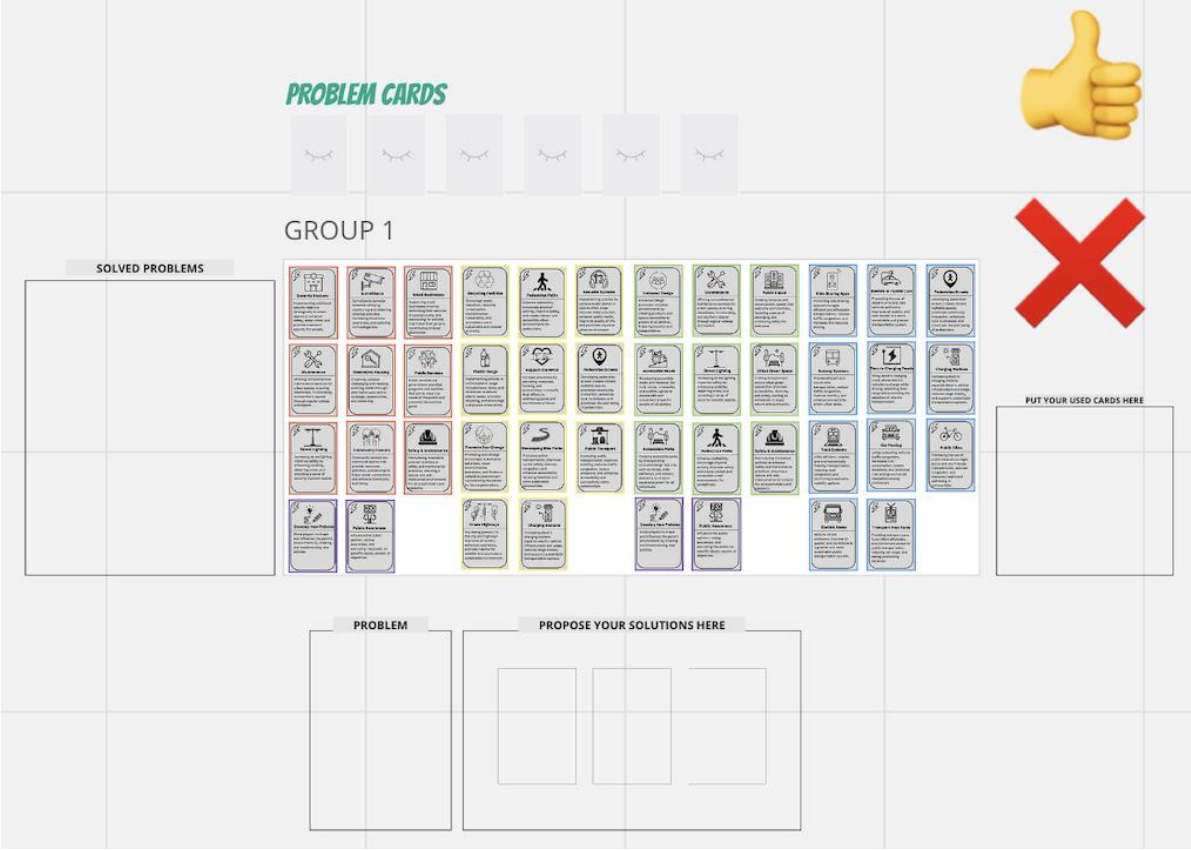

Figure 6. Game setting for the group 1 in Version B

Participants, Sampling, and Ethical Considerations

Participants were recruited through convenience sampling across three different educational settings, ensuring diversity in academic background, institutional context, and exposure to sustainability concepts:

- **Group 1 (Focus Group):** Four graduate students and recent graduates from interdisciplinary backgrounds at Concordia University.
- **Group 2 (In-Person Undergraduate Class):** Twelve undergraduate students enrolled in the "Sustainability in Design: History and Theory" course at Concordia University.

- **Group 3 (Online Class):** Eleven undergraduate students from Işık University's "Living Tomorrow: Smart Buildings" course.

All student participants had prior exposure to sustainable education through course lectures, ensuring a foundational understanding for gameplay evaluation. Only some of the participants in Group 1 did not have any educational knowledge on sustainability.

The research protocol followed standard ethical guidelines for educational research. Participants were informed of the purpose and voluntary nature of the study and gave written or verbal consent to participate. No identifying information was collected, and responses were anonymized during analysis.

Evaluation Tools, Experiment Setup, and Evaluation Process

Data collection involved both quantitative and qualitative methods:

- Pre-game survey evaluated baseline understanding of sustainability and SDG 11.
- Post-game survey (Figure 7) included 5-point Likert-scale items and open-ended questions across four categories: (1) gameplay experience, (2) sustainability knowledge, (3) attitudes and awareness, and (4) interaction, engagement, and dialogue.
- Observational data (notes during gameplay and debriefs) provided contextual insights into team dynamics, rule comprehension, and emergent behavior.

Surveys were adapted from Scurati et al. (2023) and tailored to reflect the learning goals of each game version. Both quantitative (5-point Likert scale) and qualitative (open-ended responses) data were collected. The data provided insights into the game's usability, educational value, and ability to promote discussion and systems thinking. No participants repeated the game, ensuring unbiased first impressions.

Figure 7. Post-game questionnaire

Results

Focus Group Evaluation (Version A – Group 1)

A preliminary focus group was conducted on July 14, 2023, at Concordia University to test the first iteration of the *Next-Gen Islands* board game. The group included four participants: two graduate students from architecture and two from unrelated disciplines. This session aimed to identify usability challenges, gauge initial reactions, and inform refinements for the next iteration.

The setup balanced facilitation and observation: one researcher introduced the rules while participating in gameplay, and another took notes and posed reflective questions. This dual approach allowed for deep insight into player behavior and cognitive engagement.

Participants appreciated the discussion-based nature of the game, particularly open-ended action cards that prompted collaboration and debate. However, they also found the mechanics overly complex.

Key issues included:

- Lack of clarity in rules and card functions
- Difficulty tracking progress without visual clues
- Confusion over uncategorized cards and game flow

Constructive suggestions included:

- Color-coded instruction cards for each SDG target
- Improved visual hierarchy on the board
- Enhanced illustrations and iconography
- More structured approval rules for gameplay decisions

This feedback directly informed the design of Version A.2, demonstrating the value of participatory input in refining educational tools. The group confirmed the game's potential for promoting reflective thinking but highlighted the need for streamlining to reduce cognitive overload, which is a key insight that shaped later versions.

In-Person Playtest and Survey Results (Version A.2 – Group 2)

The second iteration of the board game was tested during the ninth week of the undergrad course "Sustainability in Design: History and Theory" at Concordia University. Twelve students participated after completing eight weeks of related coursework, providing a sound foundation for engaging with the game's content.

To evaluate the playtest, a mixed-methods approach was employed, combining quantitative data from Likert-scale questions with qualitative feedback from open-ended responses. This analysis method was chosen to provide a comprehensive understanding of participant experiences: the Likert scale items (rated on a 5-point scale from 1 = Strongly Disagree to 5 = Strongly Agree) offered measurable indicators of agreement across key dimensions such as enjoyment, engagement, and clarity, while the qualitative comments provided contextual depth, explanations, and nuances that helped interpret the numerical scores. For instance, neutral Likert ratings (e.g. 3 = Neither Agree nor Disagree) could be clarified or contextualized by participants' descriptive feedback, revealing underlying positives or suggestions that might not be captured in averages alone. Descriptive statistics (e.g., means and distributions) were calculated for the Likert items, and qualitative data were thematically analyzed by identifying recurring patterns, such as specific praises or recommendations, to triangulate findings and ensure robust conclusions. This integration allowed for a more balanced assessment, avoiding overreliance on quantitative data where participant elaboration could refine interpretations.

Post-game survey results (Figure 8) showed varied responses on the Likert-scale items. For questions related to enjoyment and engagement (Category-1: Q1, Q3, Q4), 7 participants out of 12 rated 4-agree, with a notable proportion of “5” ratings indicating neutral positions for some participants. However, when supported by qualitative feedback, these results suggested that participants generally found the game enjoyable and engaging, particularly in terms of collaborative gameplay and group interaction, though not uniformly “highly” so, as the neutral scores reflect areas for improvement. For example, several students described the game as “fun and interactive” in their open-ended responses, emphasizing how group discussions “sparked interesting conversations” and “made sustainability feel more relatable,” which contextualized some neutral ratings as stemming from initial confusion rather than disinterest. In contrast, the clarity of the rules (Category-1: Q2) received lower scores (4 people rating 2-disagree), with qualitative comments consistently highlighting that the initial explanation was insufficient. Participants recommended providing printed rule sheets for reference during play, noting that this would address early frustrations. That said, many appreciated the verbal guidance offered during the first round, which helped them grasp the mechanics more effectively in real-time and contributed to positive engagement once underway. Additional suggestions included incorporating a greater number of problem cards to deepen educational value and provide more opportunities for critical engagement, while introducing empty problem cards later in the game to avoid overwhelming players early on.

In terms of knowledge acquisition (Category 2: Q1), Likert scores were moderately positive, with students reporting they did not learn entirely new sustainability concepts but gained greater awareness of the diversity and the complexity of potential solutions related to sustainable urban development. Qualitative responses reinforced this, with many highlighting that the clearly labeled keywords on the action cards helped connect specific strategies to broader sustainability goals. This indicates the game served effectively as a reinforcement and application tool rather than an introducer of novel content, aligning with its design intent.

Responses concerning sustainability awareness and attitudes (Category-3: Q2) were largely neutral on the Likert scale, which was anticipated given that most students played the game only once. Nonetheless, qualitative feedback emphasized reinforcement of understanding in environmental and social dimensions of sustainable cities, with some participants reporting renewed motivation to take action in their communities, citing both course content and the game as catalysts. Notably, several pointed to a desire to contribute to a livable future for coming generations as their primary inspiration.

Finally, feedback on interaction, discussion, and interest (Category-4: Q1 and Q2), although showed lower Likert scores, supported by positive qualitative descriptions of the game as a useful medium for practicing communication and collaborative reasoning. While some participants noted in comments that the problem-solving aspect felt somewhat limited due to the straightforward nature of the action cards (Category-4: Q3), they still valued the structured debate opportunities. Several expressed that the game encouraged deeper thinking about sustainability and inspired conversations beyond the classroom, recommending more real-world examples and emphasis on peer collaboration to enhance dynamism.

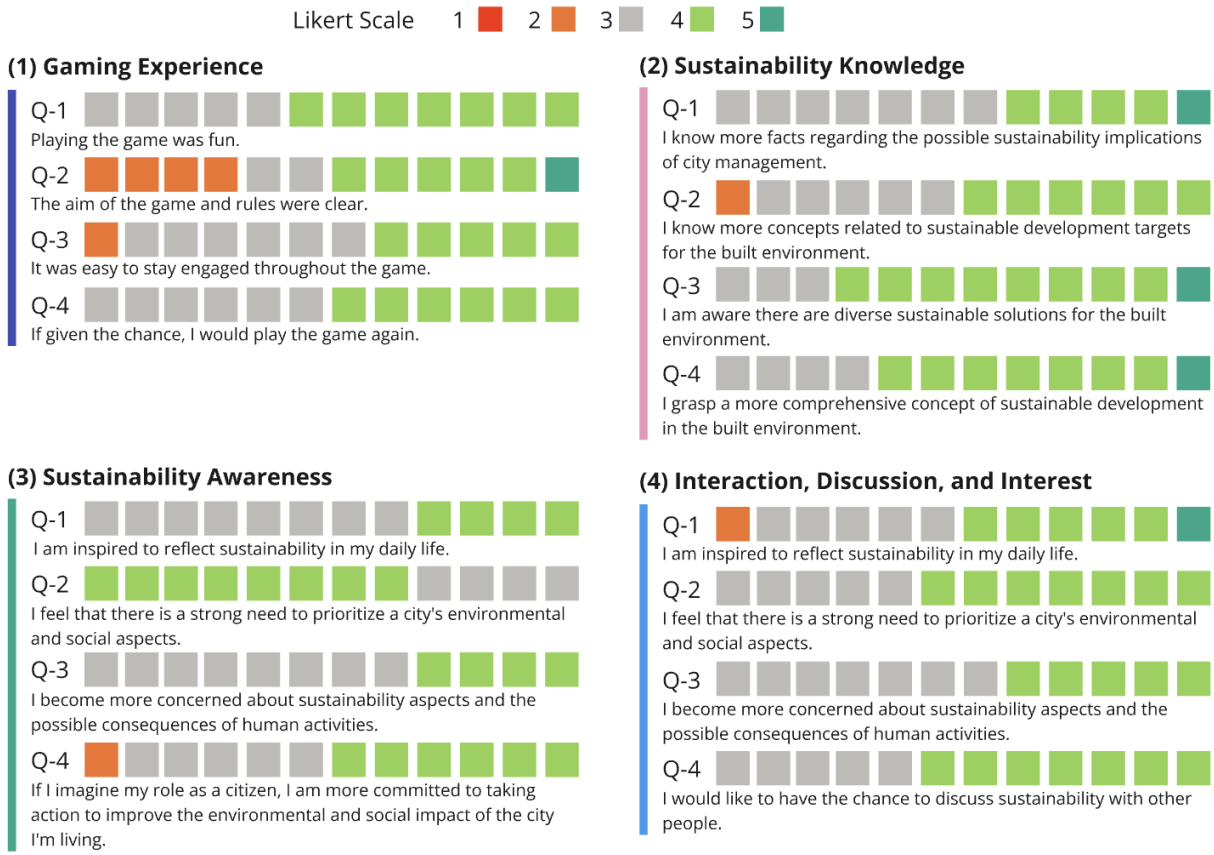

Figure 8. Group 2 post-game survey answers for all categories

During the session, observations aligned with survey findings: students understood the game mechanics more effectively through active participation rather than pre-game explanations alone. This underscored the need for simpler, more concise rule presentation to reduce initial confusion and support smoother gameplay. An integrated “how to play” guide that initiates the game and walks players through the first steps could significantly improve understanding and ease the learning curve. Despite these challenges, students showed strong interest, engaging enthusiastically in discussions, exchanging ideas, sharing humor, and asking thoughtful follow-up questions.

Based on these integrated insights, particularly the neutral-to-positive Likert trends contextualized by qualitative recommendations regarding complexity, Version B was developed with a focus on collaborative problem-solving, streamlining mechanics for better accessibility engagement.

Survey Results (Version B – Group 3)

The third workshop was conducted with undergraduate students from Işık University’s Interior Architecture and Environmental Design Department, as part of the elective course, “Living Tomorrow: Smart Buildings.” Taking place in the sixth week of the course, after five weeks of sustainability-focused lectures, the workshop assessed the educational and interactive potential of Version B, the digital adaptation of the board game. Eleven students participated via Miro, an online collaborative platform. One researcher guided setup and briefly explained rules before play began. Each participant completed both pre- and post-game surveys to

evaluate learning, interaction, and overall experience. The same mixed-methods analysis was applied in this game-play and survey as well, integrating quantitative Likert-scale data with qualitative open-ended responses.

Post-game results (Figure 9) revealed generally positive Likert trends. For enjoyment and ease of understanding (Category 1: Q1, Q3), scores were high, most responses in the 4-5 range. Qualitative feedback aligned strongly, with participants describing the game as “fun” and “engaging,” and several expressing eagerness to replay it (Category 1: Q4). The streamlined digital format and clear objectives were frequently praised in comments, supporting the conclusion that participants broadly found the game highly enjoyable and engaging, despite occasional neutral scores reflecting individual variability. Some suggested enhancements such as “bonus actions” or surprise elements to further boost dynamism.

On the sustainability knowledge, the Likert responses were neutral to positive, with participants reporting exposure to new concepts and a wider array of sustainable city management strategies. Open-ended answers reinforced that the action cards were identified as particularly effective tools for learning, due to their clarity and the way they presented concrete, actionable solutions. Students noted that the cards not only introduced them to unfamiliar approaches but also facilitated productive group discussions, making complex topics more accessible.

For sustainability awareness and attitudes, Likert agreement was neutral to strong, with most participants agreeing the game prompted deeper reflection on environmental issues and personal agency. Qualitative responses consistently cited a desire to help create a livable world for future generations as a core motivator for behavioral change, adding emotional depth to the numerical trends.

Interaction and engagement received strong endorsement, with qualitative data emphasizing playful yet substantive dialogue, critical thinking, and communication practice in a collaborative setting (Category 4: Q1, Q2, Q3). Participants frequently stated the game motivated sustainability conversations beyond class (Category 4: Q4) and saw potential for civic applications. Suggestions included integrating similar mechanics into community events, seminars, or online forums to sustain dialogue.

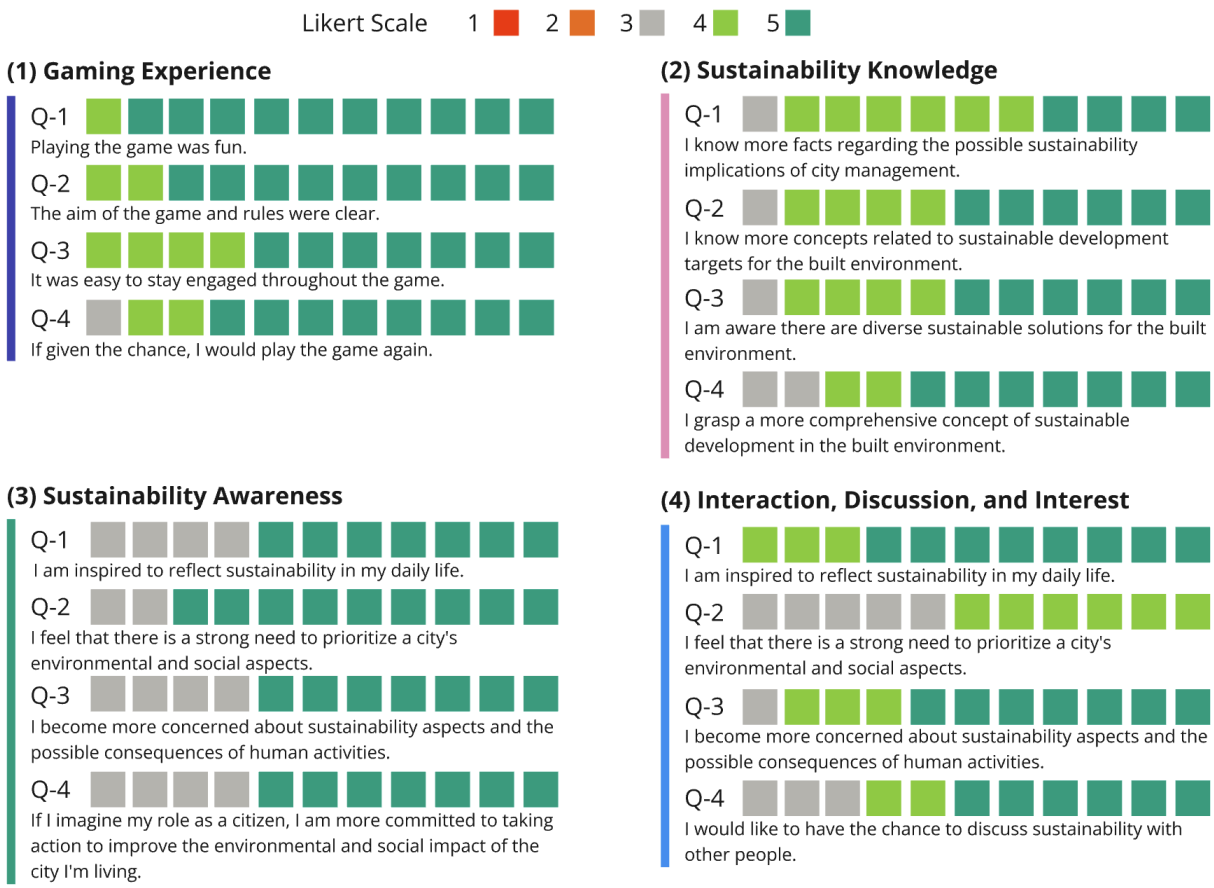

Figure 9. Group 3 post-game survey results for all categories

Overall, the integrated analysis confirms that Version B's simplified structure, particularly the focused set of action cards, reduced cognitive load, enhanced accessibility, and supported meaningful engagement. The digital format proved intuitive and educationally effective, validating its design for a public-facing installation aimed at fostering informal learning and civic discourse on urban sustainability.

Third Iteration: Toward a Digital Game Installation for Public Engagement

The findings from the focus group and two pilot workshops provided valuable insights into how serious game design can be optimized for sustainability education in informal learning settings. A key takeaway from all test groups was the importance of simplifying gameplay mechanics without diminishing the depth of discussion. Participants consistently responded positively to collaborate decision-making, especially when problem-solving tasks were clearly framed and manageable within short timeframes. These findings directly influenced the design of the upcoming digital installation, "Next-Gen Montreal," which is intended for public interaction in urban spaces.

The installation draws inspiration from water pollution and the urgent need to act on it. Therefore, the digital screen flows as a river, when played by many users, it is clean and colorings are natural greens and blues, but when it's not being played for a while, the river becomes desolated, creating abstract unnatural forms and turning into red (Figure 10).

Given the transient nature of public engagement with installations, where most individuals spend only a few minutes, the digital version is intentionally streamlined. Instead of involving complex mechanics, it focuses on a single core interaction: players choose a category aligned with SDG 11 (e.g., housing, transportation, etc.), are presented with a contextual problem, and then select two of three possible solutions (Figure 10). Because none of the options are strictly "correct" or "incorrect," this structure encourages players to prioritize values and trade-offs based on their understanding and preferences. This design draws on pedagogical principles from constructivist and experiential learning theories, which emphasize the learner's role in making meaning through active choice and reflection (Kolb, 2014). Projectors reflect the screen on the curved surface and motion sensors offer touchless interaction. There's a time constraint, represented by the answers sliding down the screen indicating the time will be up. To enhance engagement and reinforce impact, the game generates a visual outcome: an AI-produced image representing the cumulative effects of the selected solutions. The result is then plotted on a digital map of Montreal as a symbolic "citizen contribution," visually accumulating collective input and reinforcing the idea of shared responsibility in shaping sustainable cities.

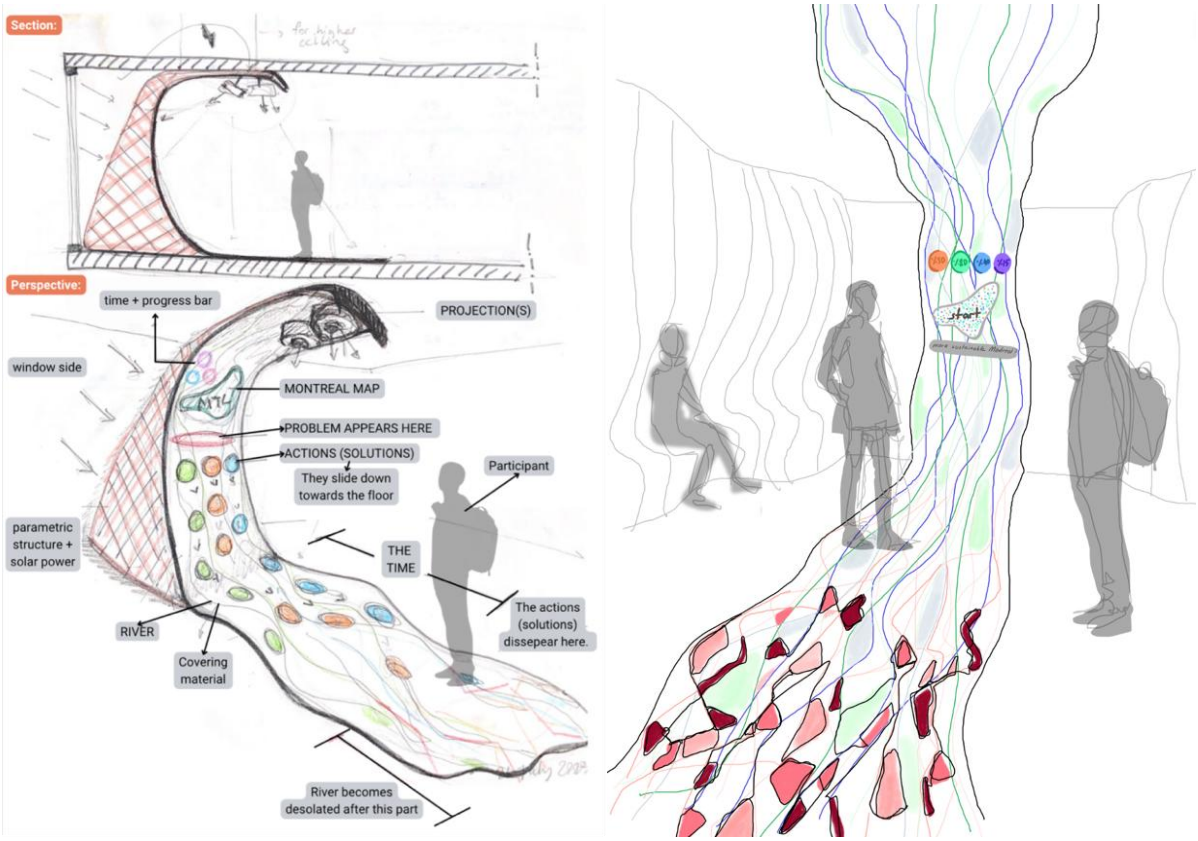

Figure 10. Initial idea sketches for the digital game installation

Importantly, this design evolution was not only driven by usability but also by educational considerations. The analog game trials revealed that while students valued the collaborative experience, many encountered barriers due to rule complexity, dense mechanics, or unclear instructions, particularly in early rounds. These barriers risk detracting from the core educational goals. Streamlining the interface as gameplay for the digital version directly addresses this issue, while still promoting systems thinking, a critical learning outcome in sustainability education (Gatti et al., 2019).

Moreover, while participants reported increased awareness and motivation, the evaluation relied primarily on self-reported perceptions, which introduces limitations. The possibility of novelty effects, self-selection bias, and limited exposure time must be acknowledged. Future evaluations of the digital game will need to incorporate triangulated data, combining qualitative interviews with performance-based measures or longitudinal tracking to assess changes in attitudes or behavior overtime.

The development process for Next-Gen Montreal continues to follow a Research through Design approach, enabling iterative prototyping, user testing, and refinement. The first prototype for the digital game has been developed. The user interface is shown in Figure 11. A clear road map that outlines internal testing, student trials, public presentation, and repeated revisions based on user feedback is also designed (Table 1). Semi-structured interviews and post-game surveys will be used in the next testing phases to generate richer evaluated data, particularly regarding how users interpret the visual outputs and how the game influences their understanding of sustainability in urban contexts.

By grounding design decisions in empirical insights and educational theory, the Next-Gen Montreal project moves beyond mere gamification to offer critical, participatory tool for sustainability learning in the public realm. The approach reflects a growing recognition that learning does not occur only with informal institutions but also through meaningful, interactive experiences in everyday environments.

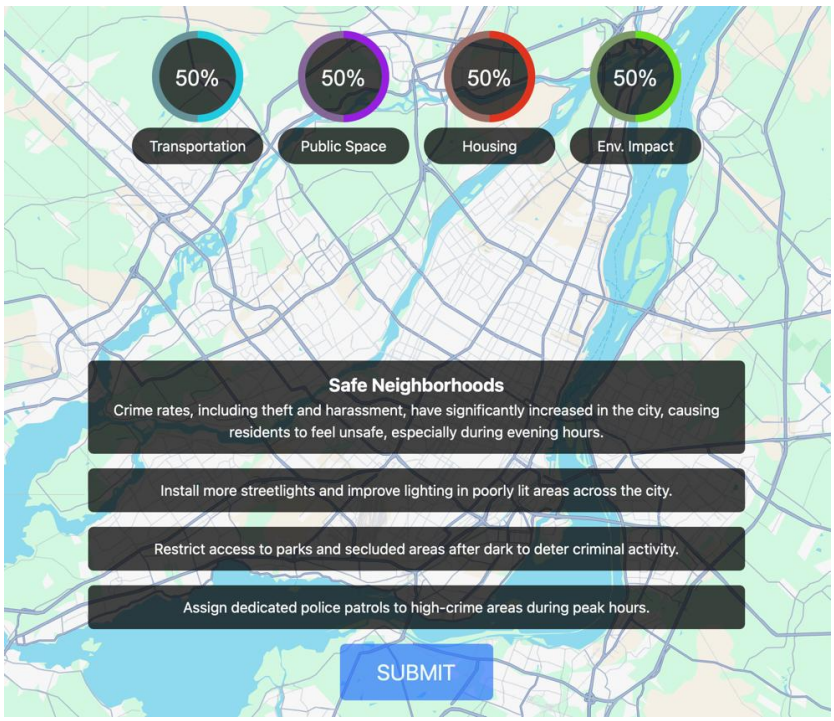

Figure 11. First prototype of the Next-Gen Montreal digital game

Interactive Narration for the Public Installation

The digital installation operates in an engaging, gesture-driven sequence designed to draw passerby into collaborative sustainable challenges.

1. Stand-by Mode: A dynamic river graphic flows in the background, overlaid with a Montreal Island map. Progress bars track advancement across key urban categories (housing, urban space, transportation, waste). An inviting prompt appears, such as “Join the challenge to make Montreal more sustainable!” or “Would you like to contribute to a greener Montreal?”
2. Player Approach: Upon detection, the prompt transitions to a welcoming message, such as “Welcome to Next Gen Montreal! Select a category to improve.” Users choose via hand gesture.
3. Gameplay Cycle:

- A sustainability problem appears on-screen.
- Three solution cards emerge after a brief pause; multiple selections are allowed, including one intentionally tricky option.
- A countdown begins as cards slide downward.
- Players discuss, decide, and select solutions by pointing.
- Chosen cards ascend; a generative image visualizes the outcome.

4. Continuation or Completion:

- Players are asked to continue (yes/no via gesture).
- No: The image shrinks into a colored pin (category-specific) and is placed on the map, accumulating with prior solutions to show collective progress.
- Yes: A new problem appears, and the cycle repeats.

This loop ensures intuitive, discussion-rich interaction while progressively mapping user-driven improvements across the city.

Materials

A significant challenge is presented by the development of a sustainable and energy-efficient digital media installation, due primarily to the substantial energy consumption inherent in the required technology. The question of how an energy-efficient digital media installation could be created was thus prompted. Collaboration was therefore engaged with Negarsadat Rahimi, whose work focuses on environmentally adaptive and energy-efficient eco-façade applications through parametric architecture. A parametric architectural shell was designed in partnership, incorporating sustainable materials to ensure environmental adaptivity and energy efficiency.

Practical Applications of the Project

The project provides actionable pathways for sustainability education and civic discourse on environmental challenges. Its flexible, interactive format supports deployment across diverse settings, such as:

- Community engagement: Localized content enables reflection and collective action on region-specific issues.
- Civic interface: Integration with public datasets (e.g., Montreal’s open data) and user input creates bidirectional communication between residents and urban systems.
- Data visualization: User choices are aggregated into a living archive that maps evolving community priorities.
- Educational tool: The analog board game serves classrooms, libraries, and museums, rendering complex sustainability concepts accessible and engaging.

Path to Implementation

Immediate steps toward realizing the Next-Gen Montreal installation are outlined in Table 1. Analog and digital prototypes were created to test educational efficacy and interaction mechanics. Developed via participatory design, these prototypes replicate the third iteration's core logic, allowing collaborative problem-solving, negotiation, and outcome reflection. This low-fidelity approach enabled iterative refinement of mechanics and content prior to digital translation. Currently the study is on the second step: Developing the Demo Algorithm.

Table 1. Initial research design for the digital game and installation

1	**Creating a Sample Database**	Developing a database for the algorithm that includes themes, problems, solutions, results, result images, and associated impact metrics.
2	**Developing the Demo Algorithm**	Implementing a demo algorithm with a sample set of 10 problems to test functionality and mechanics.
3	**Initial Testing**	Conducting preliminary testing of the game with the developer and researchers to ensure the core mechanics work as intended.
4	**Student Testing**	Testing the game with students at Concordia University to gather initial feedback and assess gameplay by conducting post-game survey and semi-structured interviews.
5	**Presentation**	Presenting the demo game at Concordia University to engage a broader audience and collect additional feedback.
6	**Second Iteration**	Refining the game based on the feedback collected from testing and presentations.
7	**Repeat Testing**	Conducting another round of testing to evaluate the updated version.
8	**Further Iterations (if needed)**	Repeating the process of testing and refinement as necessary to achieve the desired level of interactivity, engagement, and educational value.

A conceptual framework has been presented for AI-augmented, eco-didactic installations that advance public sustainability learning. The integration of Artificial Intelligence, interactivity, and experiential learning is positioned as a potent mechanism for heightening environmental awareness and catalyzing behavioral shifts.

Spatial and social dynamics are equally emphasized: meaningful interaction emerges from the interplay of users, environment, and content. Place-based design that promotes dialogue, reciprocity, and aesthetic appeal, while upholding transparency, safety, and privacy, potentially transforms public spaces into inclusive arenas for environmental learning.

Ultimately, this foundation underpins installations like Next-Gen Montreal: playful, visually striking, pedagogically robust, and socially impactful. As AI integrates further into daily life, its strategic use for eco-didactic ends offers a timely lever for sustainable urban futures.

Discussion

The third iteration, Next-Gen Montreal, marks the transition from tabletop prototyping to a public-facing, AI-augmented digital installation. Deployed as an interactive eco-didactic interface, it synthesizes insights from prior analog playtests into a scalable, gesture-driven experience embedded in urban space.

- **Educational and Engagement Outcomes:** Quantitative and qualitative data confirm that the streamlined digital mechanics, limited action cards, clear objectives, and real-time feedback, significantly enhanced accessibility and enjoyment. Likert scores and comments highlighted the intuitive flow and discussion-rich gameplay. The digital format preserved the collaborative essence of earlier versions while reducing cognitive barriers, enabling broader participation across skill levels.
- **AI Integration and Adaptive Learning:** Generative AI was employed to visualize solution outcomes dynamically, transforming abstract decisions into vivid, context-specific imagery. This not implemented only for reinforced learning but also to evoke emotional investment, for participants to visualize “future city” scenarios as motivators for sustained engagement. Adaptive difficulty scaling, informed by playtest observations, ensured challenges remained appropriately paced, preventing the early round overwhelm noted in Version A.2.
- **Public Space Activation:** Potentially will be positioned in high-traffic civic areas, the installation functions as both spectacle and dialogue catalyst. The stand-by river animation and evolving progress pins create a persistent visual narrative of collective impact, inviting spontaneous participation. Gesture-based interaction eliminates onboarding friction, while the accumulating map of user contributions fosters a sense of shared stewardship, transforming passive observation into active co-creation.
- **Sustainability of the Medium:** Energy efficiency was addressed through proposing the use of sustainable materials, minimizing environmental footprint without compromising interactivity.
- **Limitations and Future Directions:** While the digital prototype works on paper, it is yet remain untested. Longitudinal data on repeat engagement and behavioral influence are also absent. Future iterations will incorporate live integration with Montreal’s open data APIs, enabling real-time reflection of municipal sustainability metrics. Multi-lingual support and accessibility features (e.g., audio descriptions, seated interaction zones) are planned to broaden inclusivity.

In conclusion, the third iteration successfully scales participatory sustainability learning into public space. By merging refined game mechanics, AI-driven visualization, and environmentally adaptive design, Next-Gen Montreal installation proposal demonstrates that digital installations potentially can be simultaneously playful, pedagogically rigorous, and ecologically conscientious, offering a replicable model for cities worldwide.

Conclusion and Future Works

This study explored the potential of serious games as tools for enhancing awareness and understanding of sustainable development in the built environment. Through a Research through Design methodology, the project examined how interactive, problem-solving game mechanics and collaborative discussions can support learning in both formal educational settings and public spaces. The development and testing of two game versions, an analog board

game and a digital problem-solving variant, revealed that participants were most engaged when gameplay emphasize dialogue, decision-making, and teamwork. These findings reinforce existing research on game-based learning, which suggests that active, participatory experiences are especially effective for complex topics such as sustainability.

The feedback collected from focus groups and classroom pilot tests informed the initial design of *Next-Gen Montreal*, an AI-augmented digital game installation tailored for public environments. The simplified mechanics and value-driven choices in the digital version were designed in response to usability challenges observed in earlier iterations. These changes aim to ensure that the installation remains intuitive, accessible, and engaging, even for casual passerby with limited time. By transforming abstract sustainability concepts into interactive, tangible experiences, the project contributes to ongoing efforts to make sustainability education more inclusive and impactful.

The study's core knowledge contribution lies in articulating evidence-based design principles, clarity through constraint, learning through co-creation, and engagement via adaptive visualization, grounded in structured user data rather than speculative innovation. While prior work addresses serious games in controlled environments, this research provides empirical validation for AI-mediated, place-based learning in transient public settings, offering a replicable model for eco-didactic systems.

At the same time, the study acknowledges several limitations. The evaluation relied primarily on self-reported data from short-term gameplay sessions, which may be influenced by novelty effects or participant enthusiasm. The learning outcomes were not triangulated with performance-based assessments or long-term behavioral indicators, as the primary objective at this stage was to design and test the board games as exploratory tools for evaluating didactic potential. This intentional focus limits the ability to draw conclusions about long-term knowledge retention or sustained behavioral change for the board games. While student feedback provided valuable insights into engagement and comprehension, the sample was intentionally limited in scope. Broader demographic testing was not conducted, as the primary goal was to assess the board games' didactic elements to inform the development of the AI-augmented digital version.

Looking ahead, the first Next-Gen Montreal prototype is being deployed in a campus public space for field testing with diverse users. Further research will explore opportunities for integrating the installation into civic spaces, museum and educational campaigns. Collaborations with municipal agencies, cultural institutions, and educational organizations will be pursued to scale the platform and evaluate its potential as a tool for public communication, participatory planning, and sustainability advocacy.

Through its iterative, user-centred design and empirical grounding, this study contributes to the growing body of work demonstrating that serious games, when critically designed and contextually situated, can potentially serve as powerful mediums for sustainability education and civic engagement.

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